6. ENGINE OPERATION PROCEDURE

6.1 Preparations for Starting

Preparations for starting the engine and the time required doing so vary with engine conditions.

(1) An engine out of operation without maintenance or inspection

(2) An engine out of operation for a long time for maintenance and inspection

(3) A newly mounted engine

In any of the above cases, do not start the engine without checking the engine parts, piping, and accessories as described below.

6.1.1 Preparations for starting an engine newly mounted or after a long period of non-operation or an overhaul

(1) Engine check

(a) Check the tightening torque of bolts

(a1) Check that the bolts and nuts inside the cylinder block are securely tightened.

- Main bearing stud nuts
- Crank pin stud nuts and crank pin bolts
- Piston cooling jet systems and jet nozzles

(a2) Check that the bolts and nuts inside the cylinder heads valves are securely tightened.

- Fuel injector stud and nuts
- Rock arm stud and nuts
- Cylinder head stud and nuts
- Tappet adjusting bolts and lock nuts

(a3) Check that the mounting bolts and anchor bolts are securely tightened.

(b) Checking the operation linkage

⚠ CAUTION
Make sure to close the main air stop valve, before moving the fuel control lever due to prevent unintentional engine start.

(b1) Move the fuel control lever, and check that the link pins for the fuel control layshaft and governor control link, and the knock pins and cotter pins for the levers are securely in place.

(b2) Check that, when the fuel control lever is moving, the linkage moves smoothly without lost motion.

(c)Checking the fuel injection pumps

(c1)Check the injection timing, and adjust it if necessary.

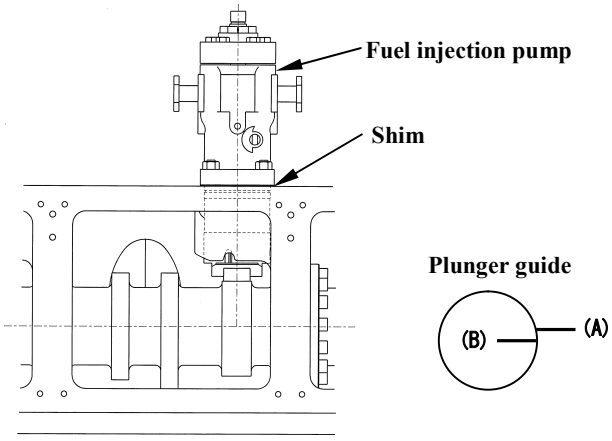
Mechanical adjustable injection timing range
Injection beginning (before combustion top dead center)
5.0～15.0 [deg.CA BTDC]

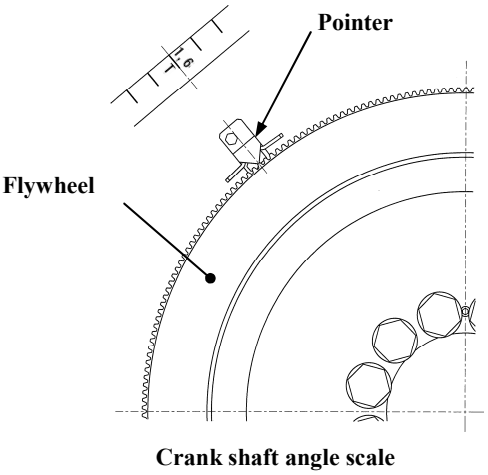
Fuel injection pump timing varies slightly from one engine to another. Refer to the shop trial performance data sheet for the fuel injection pump timing of your engine.

But the fuel injection timing can't advance beyond "NOx influencing parameter of engine" of IMO-NOx Technical File. It must be adjusted within this range.

Timing Adjustment Method

The fuel injection pumps are a Bosch type so when their injection beginning timing is adjusted their injection end is automatically settled at the same time. Injection beginning timing is expressed by the crankshaft angle (θ) where the plunger guide mark (B) visible through the plunger position check window in the injection pump body matches the mark (A) on the pump body. The timing can be adjusted by shim thickness.





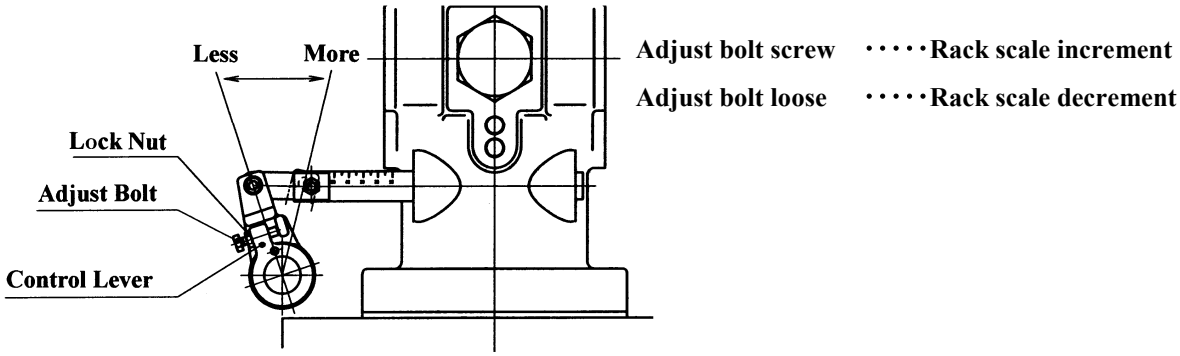
- Thin shim is advanced injection timing.
  (To increase maximum combustion pressure)
- Thick shim is delayed injection timing.
  (To decrease maximum combustion pressure)

(c2) Check that, when the fuel control lever is moved to the stop position, all of the fuel injection pumps are in the fuel cutoff state. In that case, rack scale indicate the range **between -1.0 and +1.0**. If not, adjust.

NOTE : Be sure to make this check because it is necessary to confirm that the engine will be stopped surely.

Fuel Injection Pump's Rack Scale Adjustment Method

Move the fuel control lever to the stop position, and loosen the lock nut to adjust the rack scale. After the adjustment, fasten the lock nut positively.



(d) Check the inside of the Cylinder block, in particular the cylinder liners, the connecting rods, and the crankshaft, to make sure that there is no rust.

(e) Check that the main bearings and crank pin bearings have clearances.

(f) Turn the engine, and make sure that no trouble symptoms can be observed.

(fl) After flushing the lubricating oil system, observe the following instructions prior to turning the engine. (See the attached flushing procedure)

- Fix the fuel control lever to the stop position.
- Open the crankcase doors, and check that there is no foreign matter left inside.
- Start the lubricating oil pump and prime well.
- Open the indicator cocks for all cylinders.

WARNING

Before starting the engine, check that there is nothing dangerous near it, and inform the people around the engine, that you are starting it.

CAUTION

1. When turning the engine, do not insert hand or foot at gear. There is a danger of injuring.
2. Before turning the engine, all indicator cocks open surely. If not,that is very dangerous, because crankshaft may be reverse turn.

(f2) Turn the engine, and check the following

- Check the inside of cylinders.

  Check to see if water or oil runs out of the indicator cocks.

  It indicates that water or oil remains in the cylinders. Check for the cause, and take an appropriate remedial step.

- Lubricating oil : ---- Oil leakage due to some piston trouble.
- Cooling water : ---- Water leakage due to some trouble with the cylinder heads, the exhaust valve seat rings or cylinder liners.
- Cooling water : ---- Fuel oil leakage due to some fuel injector trouble.

CAUTION

If the engine is started without having made the above check and when there is water or oil in the cylinders, a serious accident can happen as, due to the non-compressibility of the liquid collecting in the cylinders, too great a compressive force acts on the pistons and cylinder heads. (this action is called "water hammering".) If fuel oil remains in the cylinders, even a small amount of it can cause an explosion in the engine, making it turn at too high a speed.

- Make sure that the engine is turned smoothly without abnormal resistance.

  If anything is found wrong, check for the cause, and take an appropriate remedial step.

(g) Checking the rocker gears and intake and exhaust valves.

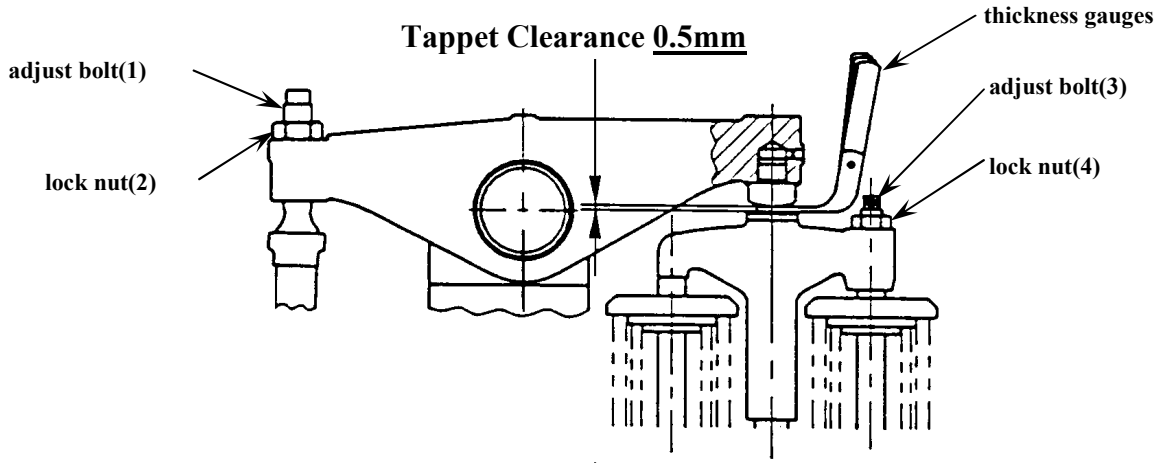
(g1) Check that the intake and exhaust valve rocker gears operate properly while the engine is turning.

- The rocker arms must be free of interference.
- The valves must properly follow the movement of the rocker arms.
- The valve guides must be free of sticking.

(g2) Adjust the intake and exhaust valve tappet clearances to **0.5 mm.**

Tappet Clearance Adjustment Method

When the engine is cold, bring the piston for the cylinder to be adjusted to the combustion top dead center, loosen the lock nut on the adjust bolt, turn the adjusting bolt(1) until the tappet clearance is **0.5 mm** as measured by thickness gauges, and then tighten the lock nut(2).



Adjustment Method of Valve Pusher Adjust Bolt(3)

Turn the adjusting bolt(3) gradually until contact the valve top face.

Check that the other side valve top has no clearance with thickness gauge.

Tighten the lock nut(4). If necessary, readjust.

(g3)Check the intake and exhaust valves timing.

-Refer to **5.1** parts adjustment standards.

(2) Checking the operation of protective devices

(Protective devices vary with specifications)

(a) Pressure switch

(a1) Checking method

- Close the cock on the pipe to the pressure switch, or loosen its joint, read the pressure at which the pressure switch operates, and check if the alarm sounds and the engine stops.
  -If the pressure gauge and pressure switches are distant, remember there is time lag.
- Check the pressure switch setting with a standard pressure tester.

(b) Temperature switch

(b1) Check the alarm by making contact.

(b2) Test the temperature switch alone, if necessary, by using boiling pot or the like.

(c) Water off relay

(c1) Slowly close the relay inlet valve, and check relay operation.

-Remember that a stop command is emitted after the timer is activated, which occurs when the water receiving plate has moved by the required angle.

(d) Check that the oil and water level alarms and control switches for the various tanks operate properly.

(e) Check that the lamps and buzzers operate properly.

-For the standard settings of the alarms and protective devices refer to Paragraph **5.3** Temperature Settings and **5.4** Pressure Settings. Check the individual devices by referring to their respective instruction manuals enclosed.

(3) Fuel oil system

(a) When diesel fuel oil is used.

(a1) If the fuel pipes have scale, rust or the like, clean them by pickling.

(a2) Discharge drains from the fuel service tank.

(a3) Check the oil level of the fuel service tank, and add fuel oil if necessary.

(a4) Open the fuel feed valve to the engine.

(a5) Start the fuel feed pump, and make sure that both the pump and motor operate properly.

-Check for abnormal noise, abnormal vibration, heat and oil leaks.

(a6) Clean the fuel oil filter (No.1, No.2), and vent air.

(a7) Check the oil leakage.

(a8) Vent air from the fuel injection pumps, fuel injection pipes, and fuel injectors.

(b) When heavy fuel oil is used.

(b1) If the fuel oil pipes have scale, rust or the like, clean them by pickling.

(b2) Discharge drains from the fuel service tanks (for heavy oil).

(b3) Operate the fuel oil heater and purifier, and circulate the heavy fuel oil through the heating circuit outside the engine. In this case, open the three-way changeover valve to the heavy oil position, and take Step(a3) through (a9) of before page.

(b4) When the fuel temperature has reached the required level, make sure it remains at that level. (Be careful not to overheat the fuel oil.)

(c) Check the fuel oil

-For details, refer to Paragraph **3.1** Fuel Oil.

(4) Lubricating oil systems

(a) System lubricating oil system

(a1) Check that the system is correctly piped, according to the specifications.

(a2) In the case of a newly installed engine or an overhauled engine, be sure to flush the lubricating oil system, and clean the piping by pickling.

(a3) Clean and check the lubricating oil cooler.

(a4) If the lubricating oil filter is a changeover open cleaning type, clean the filter, and set the changeover lever to the operating position.
-Refer to the Instruction Manual for the filters.

(a5) Check the lubricating oil properties.
-Refer to Paragraph **3.2** Lubricating Oil for details.

(a6) Discharge drains from the sump tank, and check to see if cooling water is mixed with it.
-If much water is present in the drains, make a careful check for water leakage from the lubricating oil cooler and the crankcase.

(a7) Check the sump tank oil level with the oil level gauge, and add oil if necessary.

(a8) If a lubricating oil heater is provided, operate it and heat the lubricating oil to 10°C to 20°C.(If a lubricating oil heater is used in a cold region, turn it on to heat the lubricating oil to 15°C or 30°C.)

(a9) Start the lubricating oil pump (or the standby pump if the lubricating oil pump is an engine driven type), and check the following while turning the engine.

- Check that the oil is fed.
  -If the oil is not fed, it may be due to faulty valve operation or air suction from the intake piping.
- Adjust the pressure regulating valve to the required lubricating oil pressure.
  -For the standard oil pressure, refer to Paragraph **5.3** Temperature Settings and **5.4** Pressure Settings.

・Check that enough lubricating oil is fed to various parts.

-Main Bearings	: Check that oil flows from the sides of the main bearings.
-Crank pin bearings	: Check that oil flows from the sides of the crank pin bearings.
-Piston pin bearings	: Check that oil flows along the connecting rods.
-Pistons	: Check that oil flows along the connecting rods.
	: Check that oil flows from the piston cooling nozzle.
	: Check that piston cooling oil flows straighter.
-Roller guides	: Remove the cam case covers, and check that oil flows over the cam surfaces
-Gear train	: Remove the cover of gear train inspection window, and check that oil flows.

・Check the pipe joints and plugs for oil leakage.
- If the joints and plugs are not sufficiently tightening, oil leaks on the delivery side, and air is inhaled into the piping on the suction side, and collects in the piping system, making the oil pressure unstable.

・If the filter is an automatic cleaning type, check its operation.
(Provided depending on specifications.)

・The cooler and filters tend to collect air. Open their cocks and plugs to discharge air.

・After priming for some time, check the oil level of the sump tank, and add as much oil as necessary.

・During operation, check that the motors and pumps are free of any trouble.
- Check for abnormal noise, vibration and heat.
- Carefully check that pipes disconnected or temporarily joined for flushing, or the orifices and blind plugs used for flushing are not left as they were during flushing.

・Continuously operate the lubricating oil purifier to remove foreign matter and water from the lubricating oil. (Provided depending on specifications)

(b) Checking the lubricating oil system of accessories

(b1) Hydraulic governor

Check the oil level gauge, and add the required amount of oil.

-Refer to the Instruction Manual for Hydraulic Governor.

(b2) Air cylinder

Clean the air cylinder and the linkages of VIVT drive unit, air by-pass system, and waste-gate system, and oil up them with an oilier.

(c) Other oiling points

(c1) Clean the moving parts (in particular, the fuel control lay shaft, and the governor control link) that are not oiled by forced lubrication, and oil up them with an oilier.

(c2) Grease the parts that require greasing, using a grease gun.

- turning handle etc.

(5) Cooling water system

(a) Fresh water cooling system

(al) Supply the cooling water to the engine and piping.

(a2) Turn the valves or cocks of the piping to the operation status.

(a3) Start the cooling water pump(or the standby pump if it is an engine driven type), and check the following

- Fill the piping with water, and make sure that no water leaks from the cylinder heads and cylinder block.
- Check the water leakage from pipe joint and plugs.

-If they are not completely sealing, water leaks on the pump delivery side, and air is inhaled into the piping on the suction side, and collects in the piping system, making the air pressure unsteady (as indicated by fluctuating pressure gauge readings). Eventually, this trouble will block the water passage.

- Open the air vent cocks or plugs on the piping, and discharge air.
- Check the pump seals for water leaks.

-A small amount of water leakage is normal. Check that the water leakage hole (or pipe) is not clogged.

-If much water leaks, the pump seal is defective.

-If the seal is gland packing, tighten the packing retainer.

-If it is a mechanical seal, replace it.

-If gland packing is damaged, replace it.

- During operation, check that the motors and pumps are free of any trouble.

-Check for abnormal noise, vibration, and heat.

- Check that the cooling water pressure meets the requirements.

-For the standard level, refer to Paragraph **5.4** Pressure Settings.

(a4) Check the water quantity in the fresh water (primary water) tank, and add water if necessary.

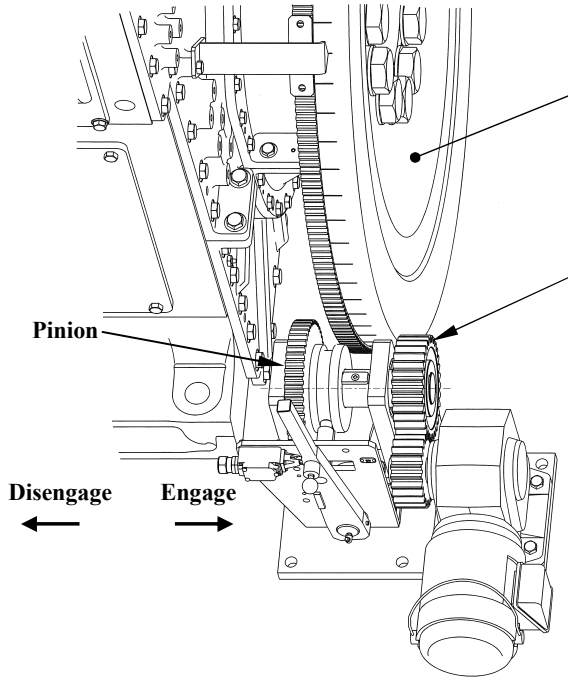
(a5) If a cooling water heater is used in a cold region, turn it on to heat the cooling water to 10°C or 20°C.

(b) Check the cooling water

-For details, refer to Paragraph **3.3** Cooling Water.

(6) Electrical motor type (Provided depending on specifications)

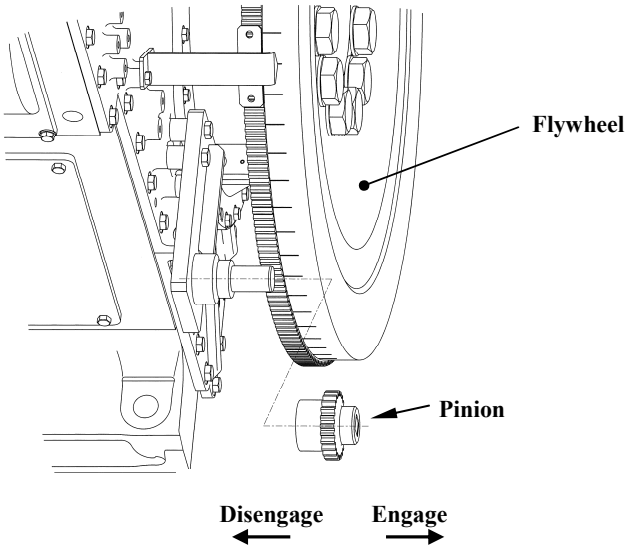
Check that, when the turning device is disengaged, the flywheel and pinion are well apart from each other.



Note: Always uses the fixation tool of the handle of the turning device in pinion connection and removal. Confirm that a handle is fixed on the fixation tool.

(7) Ratchet handle type

Check that, when the tuning device is disengaged, the pinion is removed from turning device.



(8) Stating air and mist piping system

NOTE : For the operating air system for the remote control device, refer to the Instruction Manual for Remote Control Device.

(a) Check the starting air receiver

(a1) Check the pinion of air starter and ring gear condition.

(a2) Check the pinion of air starter moves freely.

(a3) Fill the starting air receiver to the required pressure 2.5MPa ~ 3.0MPa.

(a4) After that, discharge drains by opening the drain valve for the starting air receiver.
-If drains cannot be discharge properly, check to make sure that the drain pipe is in an unclogged or place at the bottom of the receiver.

(a5) Open the valves of the starting air pipe.

⚠ CAUTION

Before turning the engine, check to no dangerous for the people near or inside the engine.

(b) Air running procedure

(b1) Start the lubricating oil pump (or the standby pump if it is an engine driven type) and check that lubricating oil is fed to various parts.

(b2) Fully open the indicator cocks for all cylinders.

(b3) Move the fuel control lever to the stop position.

(b4) Disengage the engine turning device .

(b5) If there is foreign matter in the exhaust manifold, it can damage the turbocharger nozzle, so disconnect the turbocharger short exhaust gas inlet duct, and cover the turbocharger inlet with a blind plate.

(b6) After that, push the switch "AIR RUN" at the gauge board , turn the air starter and turn the engine several times

(b7) Watch the indicator cocks during the air running for water or oil blowing out, refer to **6.1.1** (1)(f2)

(c) Check that the mist pipe is not clogged.
If the mist pipe outlet wire net is dirty and clogged, clean it.

(9) Load limiter(Governor)

Check that the load limiter is at the 100 to 110% position.(It determines with specifications)

NOTE : Never change the setting because the load limiter is set so that the fuel control lay shaft will not advance beyond the setting point.

6.1.2 Ordinary starting preparations

(a) Turn the valves and cocks of the piping to the operation status.

(b) Start each pump(or the standby pump if the pump is an engine driven type).

(b1) Check that the pressures of lubricating oil, cooling water and fuel oil meet the requirements.

-For the standard pressures, refer to paragraph **5.4** Pressure Settings.

(b2) Keep the indicator cocks opened before starting, start the lubricating oil pump (or the standby pump if it is an engine driven type) while turning the engine and pre-lubrication.

NOTE : (1) Watch for water or oil blowing out of the indicator cocks.
(2) Time of pre-lubrication, about 2 minutes.

(c) Check that the links operate smoothly when the fuel control lever is moved.

(d) Check operating about Air bypass and Waste gate Butterfly valve, using the manual device of solenoid valve panel.

(e) Perform air running

Watch for water or oil blowing out of the indicator cocks.

-Refer to **6.1.1**(1)(f2).

(f) After priming the engine, close the indicator cocks and disengage the turning device.

NOTE : Preheat cooling water and lubricating oil by operating their heaters, if provided.
Cooling water: 10°C to 20°C Lubricating oil: 10°C to 20°C

6.2 Starting the Engine

6.2.1 Before starting engine

(1) Reminders about engine stopping

(a) Before starting the engine, make sure that the engine can be stopped.

(a1) Check that, when the fuel control lever is moved to the stop position, the fuel injection pumps are in the fuel cut off position.

-Refer to **6.1.1**(1)(c2).

(b) For emergency stop, -Refer to **6.4.2.**

(c) For the method of stopping the engine, -Refer to **6.4.1** (2).

(2) Safety reminders

(a) Before starting the engine, check that there is nothing dangerous near it, and inform the people around the engine that you are starting it.

(b) Before starting a newly installed engine, or an engine out of use for a long time, or an overhauled engine, determine whether all the mechanical and electrical devices that are driven by or directly coupled to the engine are in position and in good condition, and take the steps necessary to ensure the cooperation of all persons involved.

(c) Make a safety check as necessary

NOTE : To be air running before starting engine.
Watch for water or oil blowing out of the indicator cocks.

6.2.2 Starting the engine

When all starting preparations have been made, start the engine by the following procedure.

(1) Starting conditions

(a) Check that all the pumps (or the standby pumps if they are an engine driven type) are running.

(b) Check that all pressure and temperature readings are correct.

(c) Disengage the turning device gear.

(d) Check that all indicator cocks are closed.

(e) Disengage engine load

(f) Set engines speed to about 1/2 the rated min^{-1} (idling) with the governor hand wheel or synchronizer.

(g) Close the protective device circuits.

(b) Starting procedure

(b1) Open the main valve for the starting air tank.

(b2) Move the fuel control lever to an operating position.

(b3) Push the switch "START" at the gauge board to start engine.

(b4) Close the main valve for the starting air tank.

NOTE: Make sure that the governor and fuel control system are in good condition (particularly after overhaul) because if the engine is started when something is wrong with them, the engine can suddenly operate at abnormally high speed.
If the engine appears to be running at abnormal speed, stop it immediately, check for the cause, and take a remedial measure.

6.2.3 Check immediately after starting engine

(1) Set engines speed to about 1/2 the rated min^{-1} (idling), and check the following.
Avoid a speed within the range in which engine operation is prohibited due to shafting torsional vibration.

(a) Please check the pressure gauges and thermometers whether those are correct number.
-Refer to **5.3** Temperature Settings and **5.4** Pressure about standard number.

(a1) If engine install the pump driven by engine, stop the standby pumps and check the pressures stabilize as normal level. If not, regulate the pressures with the pressure regulating valves. In this case, adjust the system lubricating oil pressure first.

(a2) If the oil pressure or cooling water pressure does not rise, stop the engine, check for the cause, and take a remedial measure. Do not restart the engine without remedying the problem.

NOTE : (1) If the lubricating oil is not preheated before starting the engine, the pressure rises higher than normal due to high viscosity; when the lubricating oil temperature rises with a resultant decrease of viscosity and the pressure. After starting the engine, wait until the lubricating oil temperature and pressure become steady.

(2) When the oil and water pressure are not normal pressure, check the following

- Leaks from the piping
- Pressure gauge trouble
- Pressure gauge pipe blocking
- Lubricating oil pump trouble
- Cooling water pump trouble
- Faulty pressure regulation by lubricating oil pump pressure regulating valve
- Air inhalation in cooling water piping
- Wrong opening or closing of each valve
- Other

(b) Check the following during engine operation, and take appropriate steps.

(b1) Check that the engine is running at a steady speed. If engine speed is unsteady (if hunting is noted), governor control trouble may be suspected. Stop the engine, and check for the cause.

(b2) Check that all cylinders are working. Open the indicator cocks, and check the burnt gas.

⚠ CAUTION
Don't touch the blow off gas from the indicator cock, because it has high temperature.

(b3) Check each part around the cylinder heads.

- Check that the intake and exhaust valve rocker gears are properly lubricated.
- Check that the intake and exhaust valve rocker gears are operating properly without abnormal noise.
- No gas must be leaking from valves.

(b4) Touch the following parts on the outside to see whether they are overheated.

- Fuel injection pumps: ------- Check for plunger seizure.
- Governor driving gear case: --------- Check for gear bushings.
- Roller guide cases
- Crankcase door: ---------- Check the main bearings and crank pin bearings.
- Liner ring: ---------- Check the cylinder liners and pistons.
- Lubricating oil and cooling water pump (if provide): ------ Check for bearings.
- Cam case door: ---------- Check the cam bearings.
- Other

⚠ WARNING
When engine parts check, do not touch it by hand directly because it has high temperature.

(b5) Check various parts for abnormal vibration.

- Exhaust manifold
- Intake and exhaust manifold
- Intake and exhaust valve gears
- Turbocharger
- Air cooler
- Governor
- Pipes
- Other

⚠ WARNING
Don't touch the bare hand during operation or after stop the engine because each parts have high temperature.

(b6) Check various parts for abnormal noise.

- Inside crankcase
- Inside gear case
- Exhaust manifold: ---------- Exhaust gas leaks
- Turbocharger: ---------- Exhaust gas leaks
- Other

(b7) Check various parts of the engine for oil, water and exhaust gas leaks.

(b8) Check the color and quantity of mist from the mist pipe of the crankcase.

-If mist quantity is excessive, or if mist color is too dark, something might be wrong with the pistons or cylinder liners.

(b9) Check exhaust gas color

-Immediately after starting the engine or during no load operation, some color is permissible if it disappears when the engine runs on load.

(b10) Check various bolts of the engine for tightness.

Note: How to deal in the case of starting error

If the engine restart immediately after starting error, unburned fuel oil staying in the exhaust system may cause explosion.

Please follow the cleaning process of exhaust system as below before restarting.

(1) Switch the starting operation to manual from control panel.
(2) Set the fuel control handle on "stop position"
(3) Check the pressure rising of lube oil by operating priming pump in manual.
(4) Do "Air running" by operating air starter.
- "Air running" is needed 3 sets "10-20 second per set " " totally approx one air tank"
- Indicator cocks and explosion detector cocks should be closed.
- Wait 30 minutes after "Air running".
(5) Check the each parts carefully that there is not some abnormality.
(6) Switch back normal starting engine operation and restart.

* "Air running" means driving engine without fuel.

6.3 Engine Operation

6.3.1 Running in

A new engine, or an engine whose pistons, cylinder liners, piston rings, main bearings, crank pin bearings, or other major working parts have been disassembled or replaced during maintenance and inspection service, must be run in.

Running in is necessary to prevent scratching and scuffing of the liner, and keeps the oil thickness properly.

(1) Running in procedure

(a) Diesel fuel oils are recommended as fuel oil. (Never use heavy fuel oils)

(b) Run the engine as mentioned below.

(b1) No-load operation

Gradually increase engine speed with care as illustrated below.

When main parts replaced
(N: Rated speed)

Engine speed (rpm)	Operating time (min)
N× 0.3	10
Stop and internal check	
N× 0.3	5
N× 0.5	30
N× 0.75	30
N× 1.0	30
Stop and internal check	
Total time	105

When main parts disassembled
(N: Rated speed)

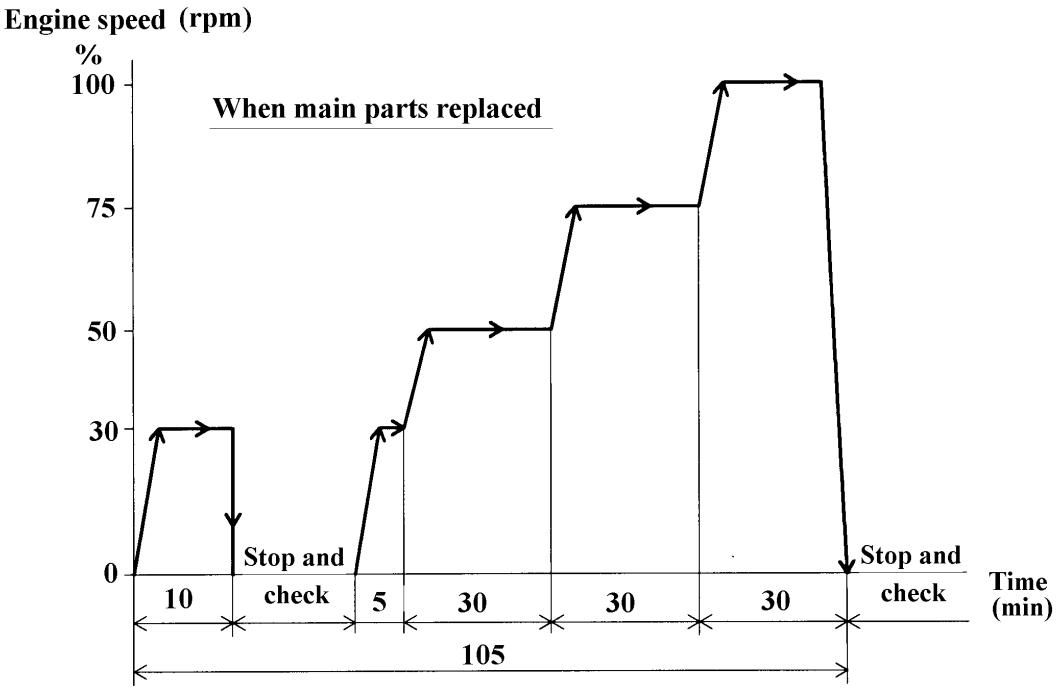
Engine speed (rpm)	Operating time (min)
N× 0.3	5
Stop and internal check	
N× 0.3	5
N× 0.5	15
N× 0.75	15
N× 1.0	15
Stop and internal check	
Total time	55

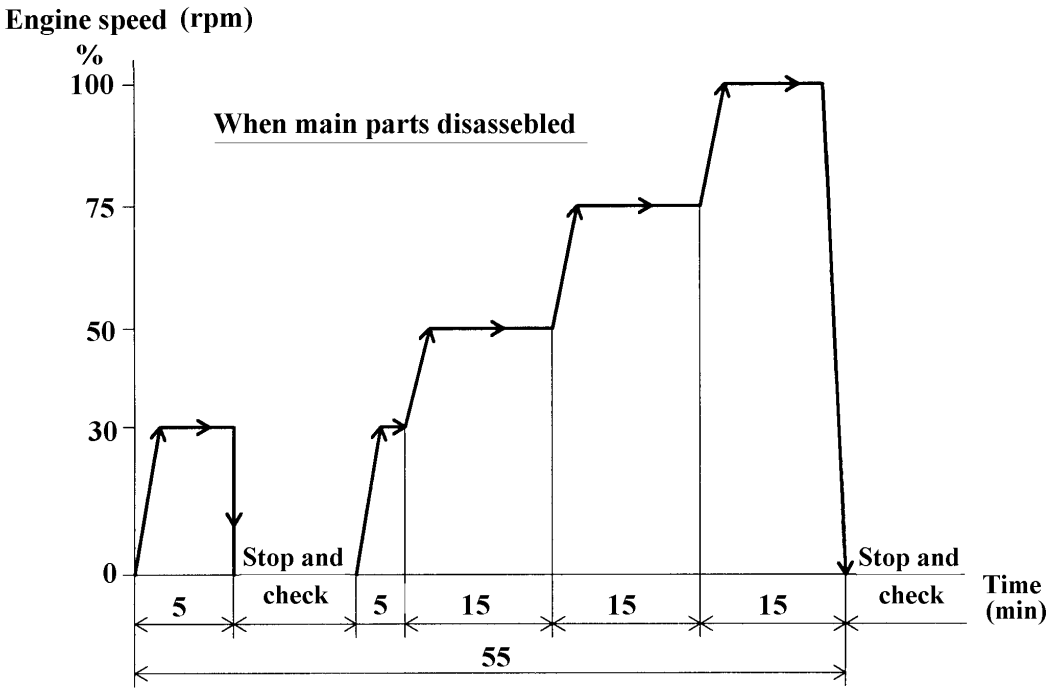
NOTE: (1) Avoid continuous operation in the speed range where engine operation is prohibited due to shafting torsional vibration. This range is indicated by the red zone on the tachometer dial. Check the tachometer for faulty indications from time to time, using a hand tachometer, or an integrating tachometer if one is installed.

(2) The internal checks do directly after engine stops, and check the each bearing temperature, cylinder liner internal surface condition, and each parts lubrication.

(3) When the minimum engine rated speed is prescribed by the setting rotation of the governor, implement running in from the setting rotation.

No-load operation





(b2) Load increase

Gradually increase engine load with care as illustrated below.

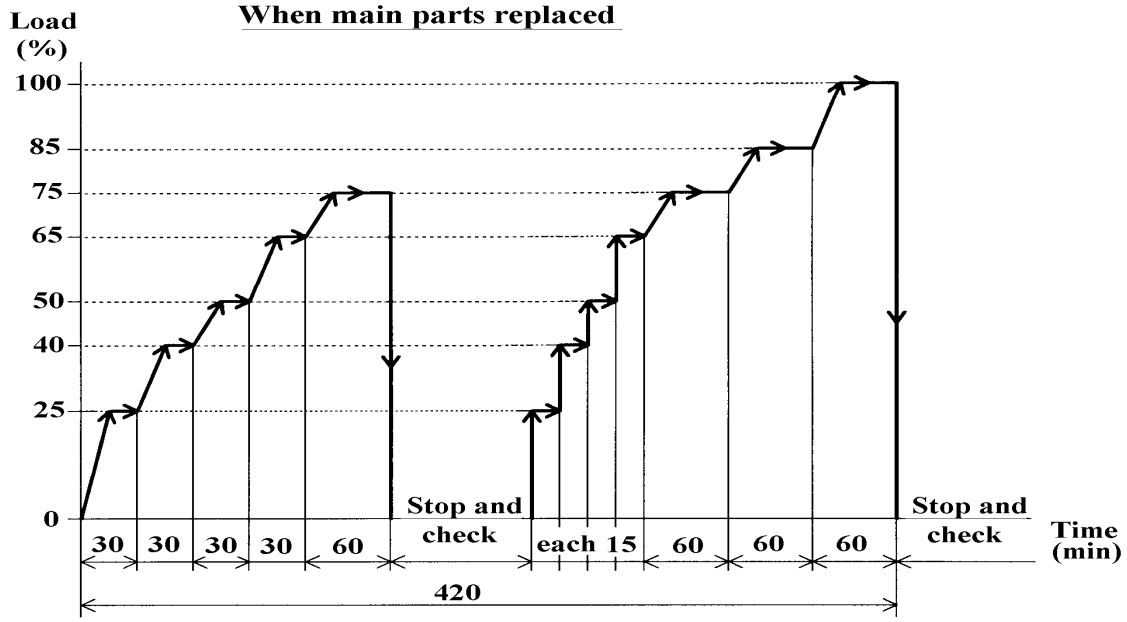
•When main parts replaced

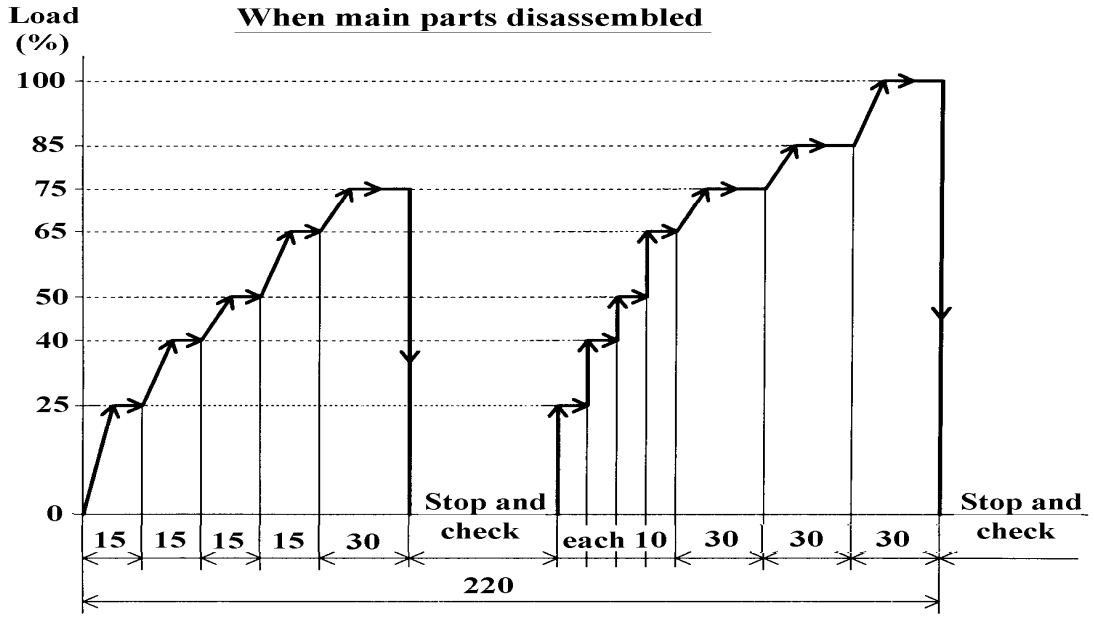
Engine load (%)	Operating time (min)
25	30
40	30
50	30
65	30
75	60
Stop and internal check	
25	15
40	15
50	15
65	15
75	60
85	60
100	60
Stop and internal check	
Total time	420

•When main parts disassembled

Engine load (%)	Operating time (min)
25	15
40	15
50	15
65	15
75	30
Stop and internal check	
25	10
40	10
50	10
65	10
75	30
85	30
100	30
Stop and internal check	
Total time	220

Load increase





(c) After starting the engine check the inside of it as described below.

No-load operation------After operation at 30% and 100% engine speeds

On-load operation------After operation at 75% and 100% loads

(c1) Remove the crankcase door, and check the main parts inside for trouble.

- Sliding surfaces of cams and rollers
- Temperatures of main bearings, crank pin bearings, and cylinder liners: Check by touching.
- Inner surface condition of cylinder liners

-If anything is found wrong, check for the cause, and disassemble if necessary.

(d) Pay special attention to the following during running in.

(d1) Abnormal noise or vibration

(d2) Overheat

(d3) Check that the bolts for various parts are tight enough and are locked.

(d4) Combustion: Check exhaust gas temperature and maximum cylinder pressure.

(d5) Colors of exhaust gas and mist

(d6) Turbocharger: Operating speed and charge air pressure.

(d7) Temperatures of fuel oil, lubricating oil, and cooling water.

(d8) Operation of accessories

(d9) Clean the lubricating oil filter at a suitable time and completely remove foreign matter.

6.3.2 Adjustment operation

Make an adjustment operation to check the performance of the engine.

(1) Adjustment operation check items

(a) Starting test

Fill the starting air tank with air, set it to the required pressure, and see how many times the engine can be started.

(a1) Perform this test when the engine is cold and without load.

(a2) Start the engine; when the sound of fuel burning is heard, stop it immediately. Repeat this start and stop.

(b) Adjust various parts of the engine as follows:

Adjust engine parts according to the shop trial performance sheet.

(b1) Adjust the lubricating oil pressure with the lubricating oil pressure regulating valve.

(b2) Adjust the maximum cylinder pressure:

-Refer to **6. 1.1** (1) (c)

(b3) Adjust exhaust gas temperature:

(c) Measure the engine performance at each load level.

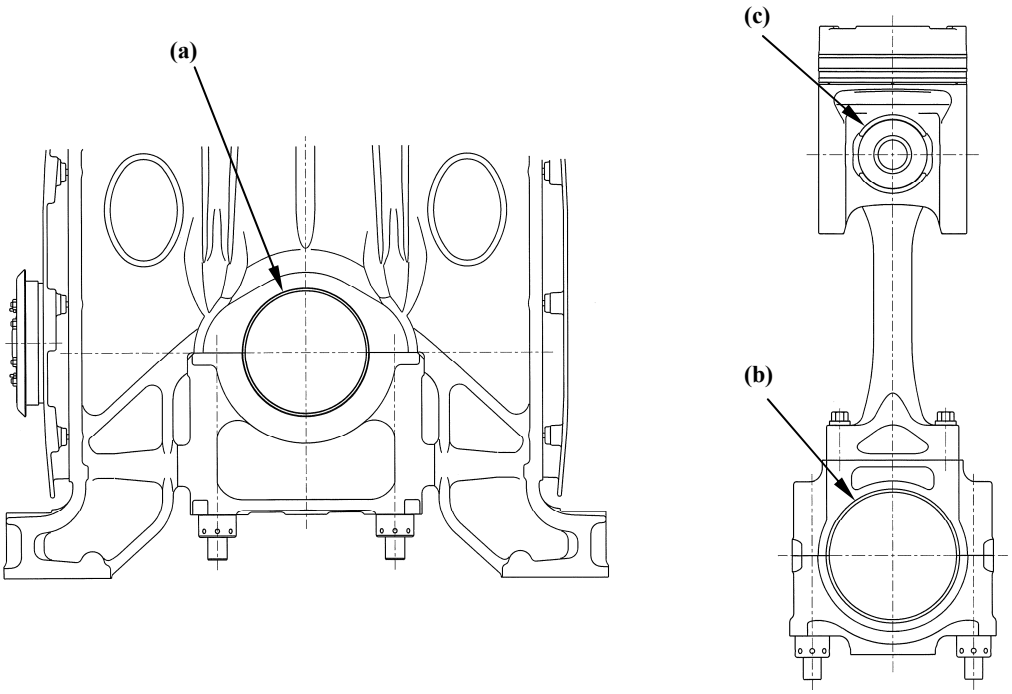
(d) Measure the temperature of each bearing.

(d1) After full-load operation, stop the engine immediately and measure each bearing temperature with a thermistor thermometer.

(d2) Reference bearing temperatures

Reference bearing temperatures are the standard engine inlet lubricating oil temperature plus the following values or less.

Measuring Point	Value to be added
Main bearing (a)	25 °C
Crank pin bearing (b)	30 °C
Piston pin bearing (c)	35 °C



(e) Governor test

Measure the momentary fluctuation rate and fluctuation rate at stabilized engine speed when the load is disengaged and engaged, and measure the time from a load change until the engine steadies (stabilizing time).

(The disengaged and engaged load determines with specifications.)

(f) Protective devices operation test

Check the pressure switches, thermal switches, and other protective devices for operation:

-Refer to **6.1.1** (2) (a), (b), (c) for the method of checking them.

6.3.3 Routine operation

(1) Load engaging procedure

As a rule, the engine should be loaded gradually. It is necessary to adjust as shown below at each stage of load increase according to the engine temperature at start. If the engine is warm when restarted after a stop, load increase intervals can be shortened accordingly.

(a) Load increasing procedure

Load increase intervals depend on mainly the following temperatures.

- Engine temperature
- Lubricating oil temperature
- Cooling water temperature
- Fuel oil temperature

(a1) Starting condition 1: Cooling water and lubricating oil temperatures between 20°C to 30°C.

Load	Normal	Sudden Load-On	Emergency Load-on
0~65%	8 min	4 min	2 min
65~90%	15 min	8 min	4 min
90~100%	7 min	4 min	2 min
Total	30 min	16 min	8 min

(a2) Starting condition 2: Cooling water 40°C or over, lubricating oil temperature30°C or over.

Load	Normal	Sudden Load-On	Emergency Load-On
0~65%	4 min	2 min	1 min
65~90%	8 min	4 min	0.5 min
90~100%	4 min	2 min	0.5 min
Total	16 min	8 min	2 min

(b) Precautions to follow while increasing load

If it is necessary to engage the load suddenly or urgently, make sure that the engine is free of any trouble, and be ready to deal with any emergency.

Be careful of the following:

- Variation in cooling water and lubricating oil pressures
- Variation in cylinder outlet exhaust gas temperature
- Variation in turbocharger speed
- Mist color and quantity

(2) Load decreasing procedure

The engine load must be decreased gradually except in emergencies.

-Refer to **6.4.1** (1).

6.3.4 Checks during operation

During engine operation, watch the pressures and temperatures of each fluid, detect anything abnormal in time by checking engine sound, vibration, temperature, and pressure, and take appropriate remedial steps. This is vital to maintaining normal engine operation.

Most daily check items are mentioned below.

(1) Fuel oil system

(a) Fuel oil service tank

(al) Check the fuel service tank oil level, and add oil if necessary.

(a2) Discharge drains from the fuel service tank.

(b) Fuel oil filter

Clean the filter if necessary.

(c) Fuel oil feed pump

Depending on specifications, an independent motor-driven fuel feed pump may be installed.

(c1) The pressure of fuel oil feed to the engine is controlled by the pressure regulating valve located between the fuel return main pipe and the service tank.

(c2) Check the feed pressure and temperature of the fuel oil to the engine.

-For standard pressure and temperature, refer to **5.3** Temperature Settings and **5.4** Pressure Settings.

(c3) Check the piping for oil leaks (on the delivery side) and air inhalation (on the suction side).If air inhalations in the piping are found, vent air by loosening the air vent plugs on the fuel injection pumps.

(c4) Check the piping clips for tightness.

(d) Shift from diesel fuel to heavy fuel (for engines burning heavy fuel)

This shift should be made after making sure that the engine satisfies the following conditions.

- Cylinder cooling water inlet temperature: Over 50°C
- Preheat the heavy fuel to raise the fuel oil temperature in the service tank.
- While the engine is operating, raise the diesel fuel temperature at the engine inlet to anywhere from 50°C to 60°C by the line heater at a heating rate of 3°C per minute.

- Keep the engine load at 40% to 50%, and change diesel fuel over to heavy fuel.
- Gradually increase the load

  Watch the variation of heavy fuel temperature at the engine inlet as the load is increased, and check that it stabilizes at the required temperature.

⚠ CAUTION

(1) It is desirable that the engine load is over 50% in continuous operation on heavy fuel. Continuous operation at less than 30% load should be avoided. Continuous operation on heavy fuel at a low load level for a long time can cause contamination of the combustion chamber and low-temperature corrosion.

(2) When heating diesel fuel to 50°C to 60°C, be very careful not to heat it too rapidly or overheat it. This is important to prevent vapor lock.

(e) Shift from heavy fuel to diesel fuel (for engines burning heavy fuel).

- Keep the engine load at 40% to 50%.
- Change heavy fuel over to diesel fuel.

(2)Lubricating oil system

(a) System lubricating oil

(a1) Check the lubricating oil sump tank oil level, record it, and check oil consumption. Add oil if necessary.

(a2) Discharge drains from the lubricating oil sump tank.

(a3) Check that the pump delivery pressure is correct.

(a4) Check that the engine inlet pressure and temperature are correct.

-For standard pressure and temperature, refer to **5.3** Temperature Settings and **5.4** Pressure Settings.

(a5) Check the piping for oil leakage and air inhalation.

(a6) Check the pipe clips for tightness.

(a7) Periodically analyze the properties of the lubricating oil.

-Refer to Paragraph **3.2** Lubricating Oil

- Take care to prevent the lubricating oil from mixing with the fuel oil

⚠ CAUTION

If the fuel oil gets into the lubricating oil, the viscosity and flash point of the lubricating oil drop, possibly causing an explosion. Check the following points for leakage.

- Oil seal of the fuel feed pump driving shaft (if attached to the engine)
- Fuel injection pump plunger, roller guide, oil pan

(b)Lubricating oil for auxiliaries

(b1)Hydraulic governor

- Check its oil level, record it, and check oil consumption. Add or change oil as necessary.

  -Refer to the Instruction Manual for Hydraulic Governor.

(3) Cooling water system

(a) Fresh water cooling system

Keep watching the pressure, temperature, and look for water leaks, and periodically check the quantity and quality of the cooling water in the water expansion tank.

(a1) Check that the engine inlet pressure and outlet temperatures are correct.

-For standard pressure and temperature, refer to Paragraph **5.3** Temperature Settings and **5.4** Pressure Settings.

(a2) Check the piping for water leaks (on the delivery side) and air inhalation (on the suction side).

(a3) Check the fresh water expansion tank for water quantity, and add water if necessary.

(a4) Periodically check the quality of the fresh water.

-Refer to Paragraph **3.3** Cooling Water.

(4) Turbocharger

A drop in turbocharger performance causes a drop in engine performance.
Thus it is important to keep the turbocharger in good operating condition.
Particularly where heavy fuel oil is used, turbocharger contamination and corrosion due to the harmful ingredients of the fuel pose problems.

(a) Check turbocharger performance.

To confirm turbocharger performance, take the following data periodically, and compare it with the shop trial data and local witness test data. Evaluate turbocharger performance, and take appropriate steps as necessary.

(a1) Periodically take operation data under the same conditions.

Compare the data (preferably prepared in graphs), and check variations in performance.

(a2) Watch for turbocharger speed variation, abnormal noise, and abnormal vibration.

If the turbocharger bearing or rotary parts have some trouble, the turbocharger generally produces an abnormal sound or abnormal vibration.

NOTE : As a simple method of checking trouble with rotary parts, stop an engine operating at dead slow speed, measure the time from fuel cut off till the stoppage of the turbocharger rotor shaft.
(1)The time is shortened if the rotary parts have trouble.
(2)If the rotor shaft runs backward after a stop, the rotary parts are out of balance.
-Turbine blades or impeller faulty.

(a3) Check for charge air pressure variation.

(5) Air cooler

(a) Check air cooler performance

A drop in air cooler performance cause a higher charge air temperature and a higher exhaust gas temperature.

(a1) Check for charge air temperature variation.

Calculate the cooling efficiency of the air cooler by the following equation.

$$\text{Cooling efficiency} = \frac{\text{Cooler inlet air temperature} - \text{Cooler outlet air temperature}}{\text{Cooler inlet air temperature} - \text{Cooler inlet cooling water temperature}}$$

- Allowable cooling efficiency: 0.60

-If cooling efficiency is less than 0.60, clean the cooling water side of the cooler.

-If cooling efficiency fails to return to more than 0.70, clean the air side of the cooler.

(6) Main parts of the engine

During engine operation, keep watching that the main parts of the engine, particularly its moving parts, are operating properly. Periodically take operation data, analyze the data, and take appropriate steps as necessary.

(a) The standard procedure is described below, though it may vary depending on the use of the engine and the extent to which the engine is equipped with automatic and safety devices.

(a1) Check around the cylinder heads

- Check the intake and exhaust valve rocker arm devices for operation.
- Check the each valve for gas leaks.
- Check for oil and water leaks.
- Check bolts and nuts for tightness.
- Check that the proper amount of oil is fed, that is, that the parts are not dry.

(a2) Check the pipe joints for water and oil leaks.
Be especially careful of fuel oil leakage because it can cause a fire.

(a3) Vent air from the piping and cooler.
Vent air from points where air collects easily (tops of piping, and cooler).
-Check the pressure gauges for abnormal readings.

(a4) Check various parts for overheat by touching or with a fixed thermometer.
-Refer to **6.2.3** (1) (b).

(a5) Check various parts for abnormal vibration.
(a6) Check various parts for abnormal noise.
(a7) Check bolts and nuts for tightness.
-Refer to **6.2.3** (1) (b).

(a8) Check exhaust gas color, mist quantity, and mist color.

(b) Engine performance journal
Periodically take engine operation data, compare the data continually, and use the results for grasping variation of the engine performance and out of order of engine condition in early stage, and preparing maintenance and inspection schedules.

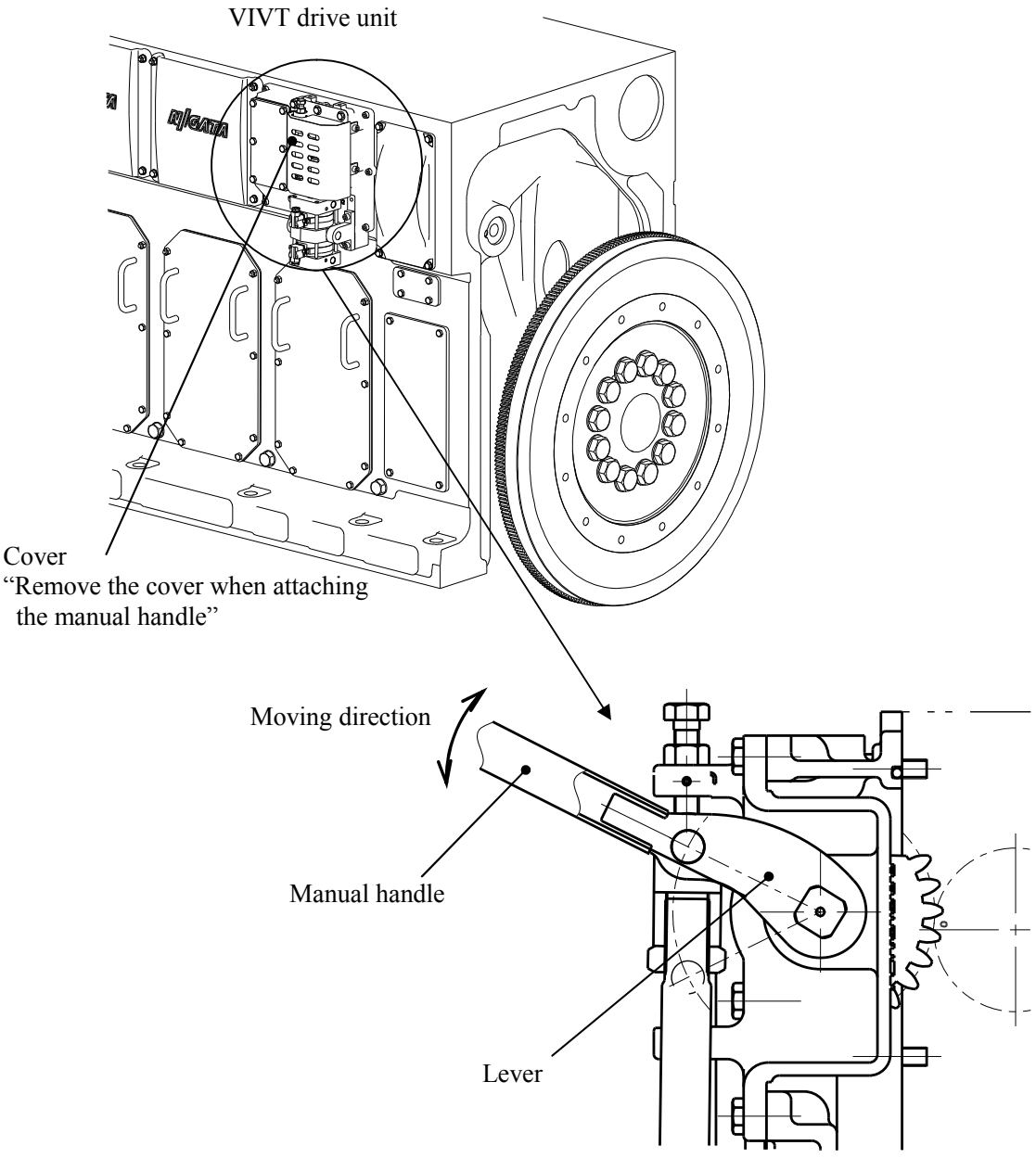
(b1) Take operation data

- Cylinder outlet exhaust gas temperature
  Cylinder outlet exhaust gas temperature difference among the cylinders must be less than ± 30°C of average exhaust gas temperature.
- Maximum cylinder pressure
  Maximum cylinder pressure difference among the cylinders must be less than 0.7MPa of the rated maximum pressure.

6.3.5 VIVT(Variable Intake Valve Timing) drive unit

(1) How to deal VIVT drive unit in the case of abnormal working

(a) If VIVT drive unit doesn't work normally, it may cause exhaust temperature rising and overpressure of cylinder. As the emergency treatment, please attach the lever to manual handle and switch the handle to early position, Intake valve timing early, and then fix the lever by attaching bracket with adjustment bolt. Black smoke would be discharged for a little period because intake air amount is limited by early intake valve timing.

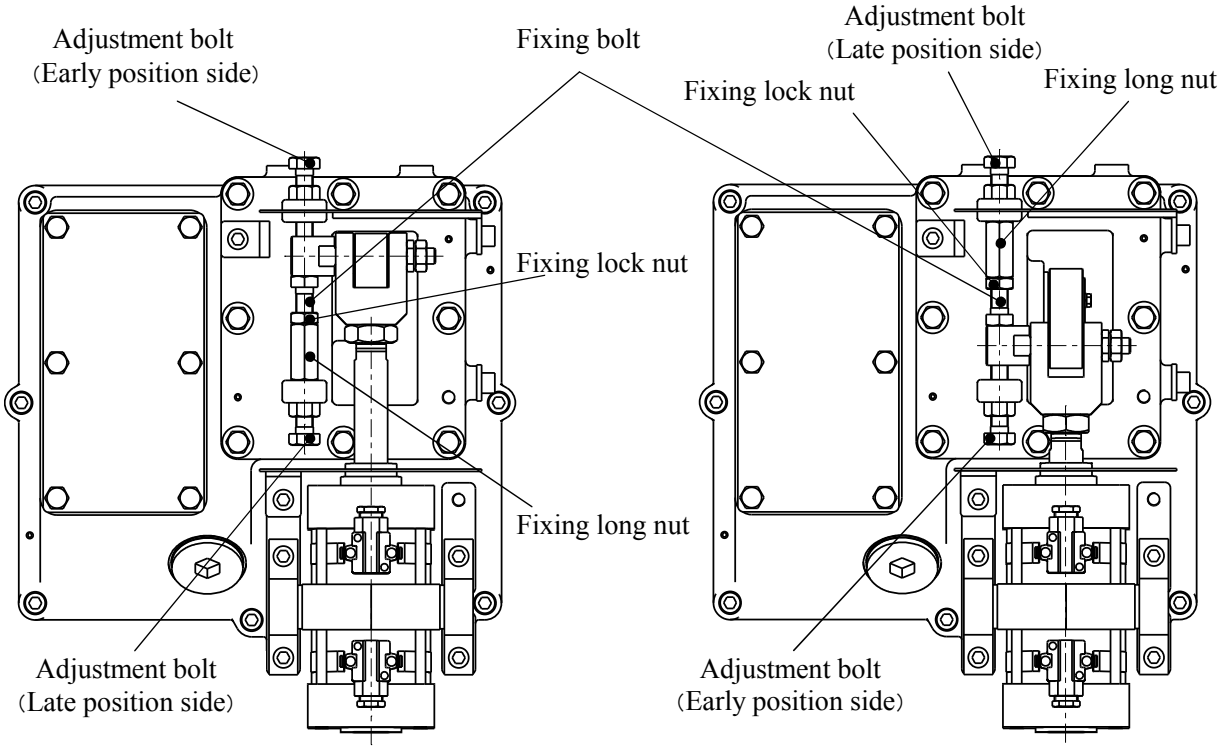


VIVT drive unit at view from side

NOTE : (1) As this treatment is just for emergency, please don't keep using but solve the root cause and repair it as soon as possible

(b) Fixed places of early position

NOTE: (1) Setting of early and late position is different depending on rotation direction of engine.



Engine rotation direction is Clock Wise (At view from the flywheel)	Engine rotation direction is Counter Clock Wise (At view from the flywheel)

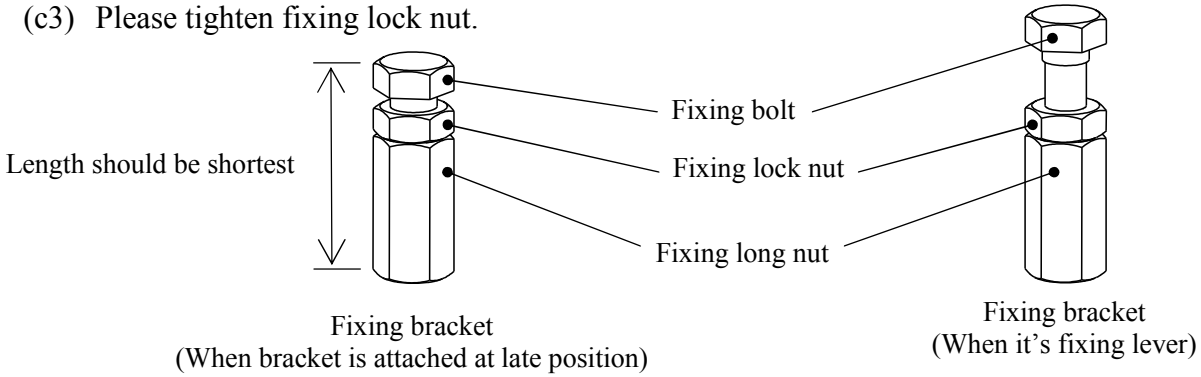
NOTE: Please don't remove adjustment bolt of early position side and don't change alignment

(c) About attaching fixing bracket

(c1) To make fixing bracket, please assemble fixing long nut, fixing lock nut and fixing bolt. Total length should be shortest at this time.

(c2) Please attach the fixing bracket ,assembled c1, to adjustment bolt at late position side and adjust length until it can fix the lever.

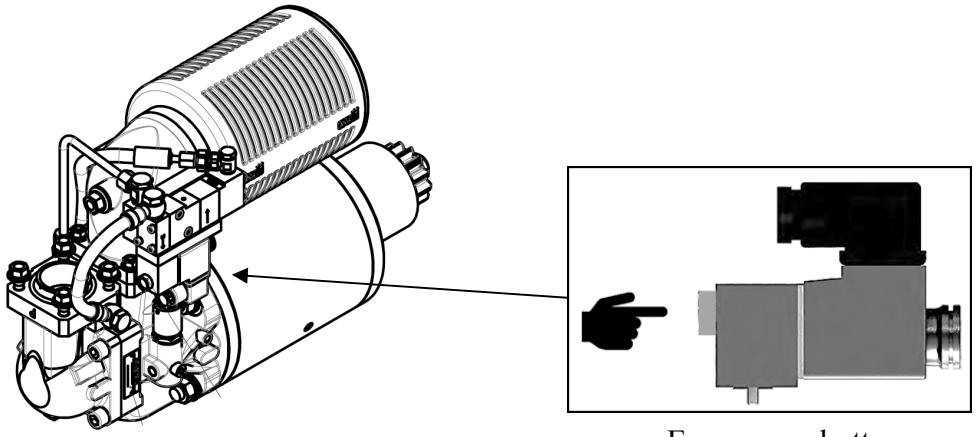
(c3) Please tighten fixing lock nut.



6.3.6 How to deal for malfunction of solenoid valve of air starter

(1) In the case of solenoid valve is failure

If the solenoid valve is failure by reason of electrical error, the air starter can work by pushing emergency button.



Emergency button

⚠ WARNING
Please make sure that there are not dangerous things around the engine before starting and give notice to around people when engine starts.

⚠ CAUTION
1. This process is acknowledged in emergency situation only. 2. Please check surely that gear of turning unit is out of ring gear and make sure whether engine can start. 3. Please wear the protection glasses and ear plug because air will be emitted violently from silencer.

6.4 Stopping the Engine

6.4.1 Ordinary engine stop

(1) Steps before stopping

(a) Decrease the load to cool the engine gradually except in emergencies.

(a1) Gradually decrease the load to 50% load (operating time : 15 min.).

(a2) After operating engine at 50% load during 30 minutes, gradually decrease the load again to zero.

(2) Stopping the engine procedure

There are several ways to stop the engine, and it is necessary to be familiar with them so that, in the event that the ordinary stopping device should fail, quick action can be taken. The important point common to all methods is to cut off fuel oil supply.

(a) Push the stopping switch of control panel or remote control device.

-Normally stopping method by remote control

(b) Push the stopping switch of gauge board

-Normally stopping method at engine side

(c) Give a lowest-speed governor revolution command

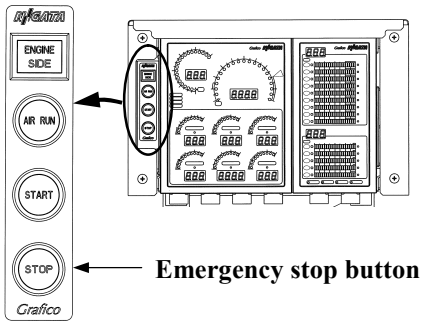
-Emergency stopping method

(d) Move the fuel control lever to the stop position

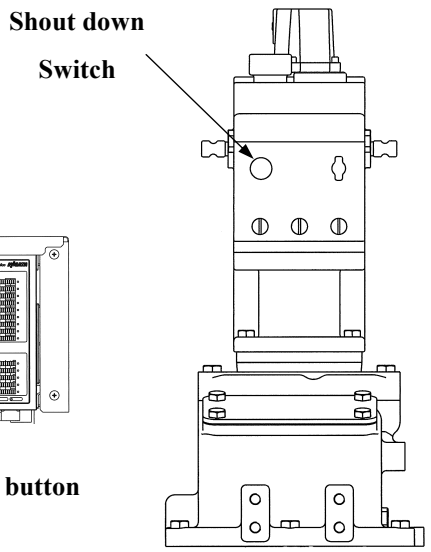
-Emergency stopping method

(e) Close the main valve at the fuel main pipe inlet

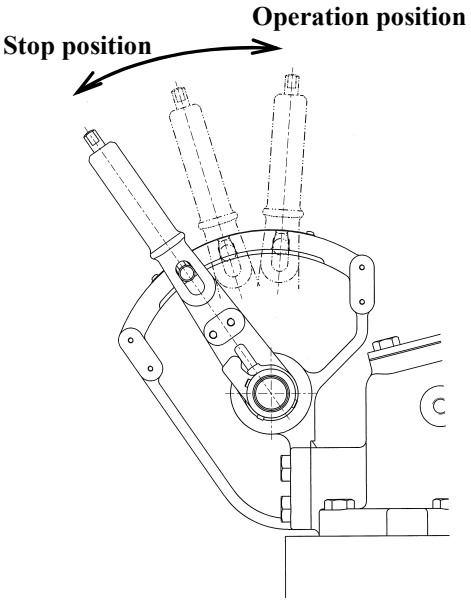
-Emergency stopping method



Gauge board



Governor



Fuel control lever
(See from driving end)

(3) Steps taken after stopping the engine

(a) Keep the cooling water pump and lubricating oil pump operating (or immediately start the standby pump if those pumps are engine driven) for about 10 minutes of after-cooling while turning the engine.

NOTE : (1) In the case of fresh water cooling system, stop the secondary pump and operate the fresh water pump only.
-To prevent rapid cooling of the engine.
(2) After-cooling is absolutely necessary because it is of utmost importance to protect the engine and to prevent the lubricating oil from deteriorating.

(a1) Open the indicator cocks during after-cooling to discharge burnt gases out of the cylinders.

(b) Close those valves, which must be closed when the engine is still.

- Fuel oil main valve, etc.

(c) Take the following steps to ready the engine for the next start.

(c1) Fill the starting air receiver with air.

(c2) Add cooling water, lubricating oil, and fuel oil if necessary.

(c3) Clean all filters.

(c4) Service and repair as necessary.

(d) Cover the stack and mist exhaust port outside the engine if the engine is stopped for a long time, or if it is rainy even though engine stop period is short.

⚠CAUTION

If the cooling water is likely to be frozen, open the drain valve on the cooling water inlet main pipe, and completely discharge the cooling water.
If the cooling water is frozen, its volume increases and will possibly crack the crank case , cylinder head and cooling water piping.

6.4.2 Emergency engine stop

(1) Where engine stop is urgent.

(a) Engine speed has increased on its own, or cannot be controlled.

(b) Fuel scale pointer has risen abnormally, and engine speed has dropped.
-This may be burnout of pistons, cylinder liners, or bearings.

(c) Bearings or other moving parts have been overheated.

(d) Engine vibrates abnormally.

(e) Engine makes abnormal noise.

(f) Crankcase mist quantity or color is abnormal.
-This may be burnout of pistons, cylinder liners, or bearings.

(g) Lubricating oil pressure has dropped suddenly.

(h) Cooling water temperature has risen suddenly.

(i) Turbocharger makes abnormal noise or vibration and is overheated.

(j) Exhaust gas temperature has changed suddenly.

(2) Steps taken after emergency stop.

If any of these symptoms is found, immediately stop the engine, check for the cause, and refrain from restarting the engine until the trouble is remedied.

-For trouble causes and remedies, refer to Chapter **8** Troubleshooting.

(a) After an emergency engine stop, keep the cooling water pump and lubricating oil pump operating (or immediately start the standby pumps if those pumps are engine driven) for after-cooling.

WARNING

Don't open the crankcase door during 20 minutes, when the engine stopped for emergency. If the crankcase door is opened immediately after a trouble, the mist in the crankcase may be fire and explode. Exercise care not to do so.
When removing the crankcase door, turn the bolts and nuts slightly to let fresh air into the crankcase so that the mist will not explode and then remove the crankcase door completely.

(b) If much mist is discharged from the mist pipe, it is because the mist pressure inside the crankcase is abnormally high. In this case, do not open the crankcase door until mist discharge rate decreases (about more than 20 minutes).

(c) In the case of engines burning heavy fuel oil, keep the line heater and fuel feed pump on to circulate the fuel oil as long as possible after stopping the engine.
If heavy fuel oil stops circulating, it may become too difficult to restart the engine.
If this occurs, the fuel oil piping must be cleaned.

6.4.3 Non-use of engine

When not using the engine for longer than a week, the following steps should be taken for engine protection.

(1) Steps taken immediately after engine stop.

Take the following steps as appropriate to the duration of non-use.

(a) Completely discharge the cooling water from the engine and coolers so no water remains in the piping.

- Otherwise, as it freezes, the water increases in volume, possibly causing cracks in the crank case, cylinder head and cooling water piping.
- To prevent various engine parts from corroding.

(a1) Open the drain valve on the cooling water inlet main pipe to discharge the cooling water from the engine.

(a2) Remove the drain plugs for the lubricating oil and fresh water coolers to discharge the cooling water from them.

(b) Spray or apply anti-corrosive oil to the shiny and sliding parts of the engine.

(b1) Starting air valve and starting air distributor

(b2) Fuel control lay shaft

(b3) Cylinder head top surface and fulcrum supporter

(b4) Other machined surface exposed parts

(c) Remove the exhaust valves or fuel injectors, spray anti-corrosive oil into the combustion chambers while turning the engine, and mount the removed valves.

(d) Check the bolts and pipes for the main parts of the engine. If anything wrong is found, immediately repair or replace the faulty parts.

(e) Put covers on the stack and mist outlet outside the engine.
Special caution must be exercised to protect the main parts of the engine (crankshaft, etc.) from rusting due to rainwater flowing backward.

(f) Ventilate the engine room.

(2) Steps taken during non-use of engine

(a) Turn the engine at least once a week to change the piston and bearing positions.

(a1) Prime the lubricating oil pump (or start the standby pump if it is engine driven), and oil the sliding parts with an oiler.

(a2) Lubricate the intake and exhaust valve rocker gears.

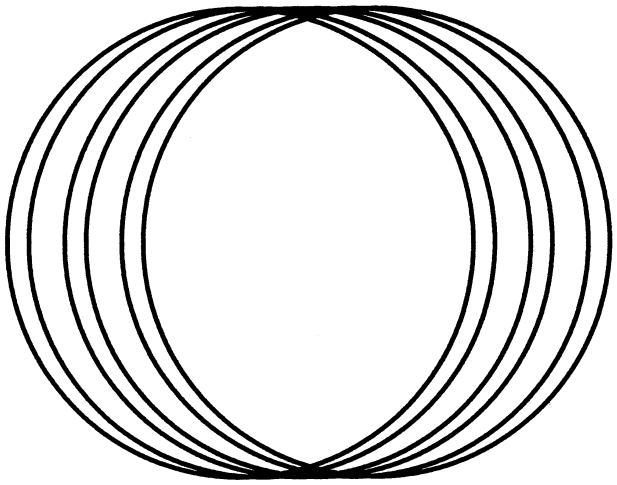
(b) Check the outside of the engine once a month for any signs of trouble.

(c) Spray or apply anti-corrosive oil to the shiny and sliding parts of the engine once a month.

(d) Remove the exhaust valves or fuel injection valves every three months, spray anti-corrosive oil into the combustion chambers while turning the engine, and remount valves.

(e) Analyze the lubricating oil properties every month.
-For details, refer to Paragraph **3.2** Lubricating Oil.

MEMO



NIIGATA DIESEL INSTRUCTION MANUAL

MG(L)28AHX

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7.5.16 Cam bearing, thrust bearing check ---------- 7-78
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7.5.22 Exhaust manifold check ------- 7-87
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7. ENGINE MAINTENANCE PROCEDURE

(ASSEMBLY AND DISASSEMBLY PROCEDURES)

⚠ **WARNING**	1. Any negligence of controlling cooling water, lubricating oil and fuel oil, and controlling the clamping in reassembly after overhaul inspection may lead to fault of the engine and result in physical accidents due to failure of parts. 2. There is a possible danger of physical accidents that may be caused when the engine is started by mistake during the inspection and repair of the air-started engine. Be sure to carry out following items to prevent the erroneous start of the engine. ・Close the main valve of stating air tank. ・Release the residual pressure remaining inside the starting air pipeline. （between the starting air-tank to the engine） 3. The engine may start abruptly without notice through the auto start signal or by remote starting. As there is a danger of entanglement etc., do not be access to rotating parts and moving parts.
⚠ **CAUTION**	1. The top of surface of foot plate, that is slippery if led with oil etc., entails the danger of tumbling and falling. Wipe off thoroughly the oily matter left on the foot plate and shoes. 2. The topside of engine intake exhaust manifold, air dust, etc., that is slippery in some cases, entails the danger of tumbling and falling. Do not step on their topside unless has been confirmed. 3. There is a danger of hands or legs being entangled during the course of grinding, and drilling work. Do not put on gloves. 4. There is a danger of your hands and legs being pinched by weight part or disassembling tools during overhaul inspection of the engine. Take precautions in handling such part and tools. 5. Be sure to put on safety goggles in carrying out the following items of work being in danger of injury to eyes. ・When handling fuel oil, lubricating oil, cooling water and inhibitor, and anti-freeze solution ・In course of washing work ・When handling battery electrolyte ・In course of fuel injection valve injection test ・In course of grinding work ・In course of intake/exhaust valve grinding work 6. There is a danger of injury to the head inside the engine room and enclosure. Be sure to put on a helmet for the protection of the head. 7. Put on protective masks since the following items of work are in danger if adverse effect upon the health due to inhalation of deleterious mist or dust. ・In curse of cleaning work with compressed air ・When handling heat insulation material (glass cloth, etc) 8. There is a danger of injury to your hands during the work inside the engine room and enclosure. Be sure to put on safety shoes for the protection of your legs. 9. There is a danger of injury to your hands during the work inside the engine room and enclosure. Be sure to put on gloves for the protection of your hands except for the of case of special work

7.1 Foreword

To maintain the engine in the best operating condition, it is necessary not only to observe and check it daily but also to perform periodic maintenance and periodically change parts. Maintenance intervals and parts life are subject to change with engine running hours, maximum engine load, the environment in which the engine is located, the kind of fuel oil and lubricating oil used, the frequency of starts and stops, and the kind of loads (low load, or varying load), and can also differ greatly with the quality of maintenance. The following maintenance and inspection standards were prepared on the basis of our experience over many years; you are advised to prepare your own maintenance and inspection schedule suited to your particular conditions based on past data.

⚠ CAUTION
(1) The parts life that is described on the following list is not guaranty one.
(2) When you check the parts and confirm the abnormal condition of the parts, replace the parts immediately. (Replace the parts , if necessary.)

7.2 Maintenance and Inspection Planning

7.2.1 Maintenance and Inspection Planning

(1) Prepare your own maintenance and inspection plan by which to perform maintenance work.
-Refer to Paragraph **7.4** and Paragraph **7.5**
(2) When maintaining this engine, considerable attention must be paid to keeping safety.
(3) Keep an inventory of the parts in stock, and have the necessary parts ready in time.
(4) Keep the disassembly tools in order at all times so that they are ready for use when they are needed in emergencies.
(5) Be sure to replace the gaskets and O-ring.
(6) When exchanging parts, use Niigata original parts.

NOTE : When you need information of engine operation and maintenance, please inform us detail of it, beforehand.

7.2.2 Table of component mass

⚠ CAUTION

When lift the heavy part, use sufficiently powerful device. (Chain block hoist etc)
When handing weighty article exceeding 20kg in weight, use a crane or hoist or allow two persons or more to engage in the handing work.
(In case of joint work also, the weight should be limited to less than 20kg per per son.)

Main parts mass table

(unit:kg)

NO	Parts	Mass/unit			Remarks
		6cyl.	8cyl.	9cyl.	
1	Main bearing cap	63	←	←	
2	Locating bearing cap	50	←	←	
3	Locating bearing bracket	130	←	←	
4	Crank shaft ass'y	2650	3380	3750	With balance weights and crank gear
5	Torsional damper	320	680	←	
6	Flywheel	510	←	←	With ring gear
7	Cylinder liner	135	←	←	
8	Liner ring	55	←	←	
9	Piston ass'y	70	←	←	With piston pin and piston rings
10	Connecting rod ass'y	92	←	←	With bolts and bearings
11	Cam shaft ass'y	340	450	500	
12	Cam gear	40	←	←	
13	Idle gear (driving end side)	110	←	←	With gear shaft
14	Idle gear (free end side)	30	←	←	With gear shaft
15	Crank gear (free end side)	45	←	←	
16	Gear case cover	110	←	←	Turbocharger on free end side spec.
17	Gear case * CWP	65	←	←	Turbocharger on free end side spec.
18	Flyer cover ass'y	53	←	←	
19	Damper case cover	85	←	←	
20	Air starter	31	←	←	
21	Cylinder head ass'y	285	←	←	With I/E valves, safety valve, indicator cook and I/E manifold
22	Rocker arm ass'y	55	←	←	
23	Fuel injection pump	42	←	←	
24	Cooling water pump	75	←	←	With driving gear
25	Lubricating oil pump	120	←	←	With driving gear
26	Exhaust manifold ass'y	235	510	460	Pulse system
27	Turbocharger	450	720	←	
28	Turbocharger bracket	630	←	←	Turbocharger on driving end side
29	Charge air cooler	510	570	580	
30	Lubricating oil cooler	270	290	300	For engine mount
31	Lubricating oil filter	120	←	←	For engine mount
32	Power take off shaft	205	←	←	
33	Power take off shaft bearing cap	75	←	←	

7.3 Maintenance schedule

7.3.1 Outline of maintenance schedule

< Time schedule of maintenance & relevant spares >

" A " Daily check - - - Refer to **7.3.3**
" B " Maintenance - - - Every 1,500 hours operation (Every 3 month)
" C " Maintenance - - - Every 3,000 hours operation (Every 6 month)
" D " Maintenance - - - Every 6,000 hours operation (Every 1 year)
" E " Maintenance - - - Every 12,000 hours operation (Every 2 year)
" F " Maintenance - - - Every 24,000 hours operation (Every 4 year)

NOTE. ( ) shows operating interval

Maintenance Class	B	C	B	D	B	C	B	E	B	C	B	D	B	C	B	F
Operation hours	1,500	3,000	4,500	6,000	7,500	9,000	10,500	12,000	13,500	15,000	16,500	18,000	19,500	21,000	22,500	24,000
For "B" Maintenance	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
For "C" Maintenance		○		○		○		○		○		○		○		○
For "D" Maintenance				○				○				○				○
For "E" Maintenance								○								○
For "F" Maintenance																○

NOTE : Above figure shall be expected in case of the conventional operating conditions of fuel, load atmosphere, etc.

7.3.2 Contents of maintenance

○ : Check & Cleaning, △Partial Check & Cleaning

● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Cylinder head	• Check the cylinder head stud bolt tightening force check		○	○	○	○	
	• Combustion chamber, intake and exhaust passage clean and check			○	○	○	
	• Combustion surface dye check			○	○	○	
	• O-ring Pipe (FV body) check					●	
Intake and exhaust valve	• Valve check, measure, dye check			○	●	●	
	• Valve guide inner diameter measuring			○	○	●	
	• Valve seat lapping			○	●	●	
	• Spring check		○	○	○	●	
	• Valve rotator check			○	●	●	
	• Exhaust valve seat O-ring replace				●	●	
Fuel injection nozzle	• Fuel injection nozzle check	○	●	●	●	●	
	• Injection pressure test, spray check	○	○	○	○	○	
	• Fuel injector body dye check		○	○	○	○	
	• Spring check		○	○	●	●	
Indicator cock and Cylinder safety valve	• Indicator cock check			○	○	●	
	• Safety valve body and valve lapping			○	○	○	
	• Safety valve spring check			○	○	○	
Piston	• Piston cleaning and check			○	○	○	2 cylinder inspect at first year
	• Piston diameter measuring			○	○	○	
	• Piston pin boss inner diameter measuring			○	○	○	
	• Piston pin diameter measuring			○	○	○	
	• Ring groove clearance measuring			○	○	○	
	• Piston ring check			○	●	●	
	• Snap ring check			○	○	○	
Connecting rod	• Crank pin bearing check			○	●	●	**
	• Crank pin stud bolt check			○	○	●	
	• Oil holes check and cleaning			○	○	○	Air blow off after Washing
	• Big end and small end inner diameter measuring			○	○	○	Uneven wear Measuring
	• Rod and big-end (upper) contact surface check			○	○	○	
	• Piston pin bush check			△		●	
Cylinder liner	• Visual check through crankcase doors	○	○	○	○	○	
	• Combustion surface, and inner surface check			○	○	○	
	• Fire ring diameter measuring and dye check			○	●	●	
	• Deglazing				○	○	
	• Cylinder liner dismount				○	○	

** NOTE) After check the condition of bearing, if necessary replace crank pin bearing and main bearing.

○ : Check & Cleaning, △Partial Check & Cleaning
● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Crank shaft	• Deflection measuring	△	○	○	○	○	△: Check it at first 500 hours
	• Crank pin and journal measuring check			○	○	○	
	• Crank pin and journal dye check					○	
	• Balance weight stud bolts tightening force check	○	○	○	○	○	
Main bearing and location bearing	• Main bearing check and clearance measuring			△	○	●	** △:Check the bearing at middle throws only
	• Location bearing check and clearance measuring				○	●	
	• Thrust bearing check and clearance measuring				○	●	
Power take off shaft bearing (Depend on specification)	• Bearing check and clearance measuring				○	●	**
Torsional vibration damper (Depend on specification)	• Disassembly and check					○	Refer to the Instruction Manual for geislinger damper
Flexible coupling (Depend on specification)	• Disassembly and check					○	Refer to the Instruction Manual for flexible coupling
Rocker arm	• Tappet clearance adjustment	○	○	○	○	○	
	• Shaft check and oil hole cleaning			○	○	○	
	• Rocker arm bushing check			○	○	●	
	• Clearance between rocker arm shaft and rocker arm bushing measuring			○	○	○	
	• Adjust bolts check			○	○	●	
	• Rocker arm dye check			○	○	○	
Cam shaft, Cam roller, Cam bearing Thrust bearing	• Cam visually check	○	○	○	○	○	
	• Roller contact visually check	○	○	○	○	○	
	• Cam bearing clearance measuring				○	○	
	• Thrust bearing check					○	
	• Cam bearing check					○	
Valve gear	• Intake and exhaust push rod check		○	○	○	○	Top and bottom pieces check, and push rod bend check
	• Tappet disassembly and check, and oil holes cleaning				○	○	
	• Roller bush check				○	●	
	• Shaft, roller pin and tappet inner diameter measuring				○	○	
	• Roller pin, snap ring and tappet dye check				○	●	
	• Tappet bearing check and clearance measuring				○	●	
VIVT Tappet shaft drive unit	• Ball bearing check			○	●	●	
	• Reamer bolt, lever check			○	○	●	
	• Rubber hose of control air check				○	●	
	• Tappet driving gear check				○	○	
	• Air cylinder check	○	○	○	○	○	

** NOTE) After check the condition of bearing, if necessary replace crank pin bearing and main bearing.

○ : Check & Cleaning, △Partial Check & Cleaning
● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Fuel injection pump	• Deflector(eye-bolt), delivery valve and plunger check			○	●	●	
	• Control rack scale position check			○	○	○	
	• Injection timing check			○	○	○	
	• Disassembly and cleaning			○	○	○	
	• Spring and plunger guide check			○	○	●	
Fuel injection pipe	• Injection pipe seat surface check			○	○	○	
	• Injection fitting seat surface check			○	○	○	
Air starter Ring gear	• Pinion gear check	○	○	○	○	○	**
	• Ring gear check	○	○	○	○	○	
	• Visual check, grease condition check		○	○	○	○	
	• Air starter overhaul			○		○	***
Governor	• Governor oil change		○	○	○	○	
	• Governor overhaul at specialized shop			○	○	○	Send to supplier
Governor driving device	• Gear contact and pitting check				○	○	
	• Backlash check				○	○	
	• Ball bearing check				○	●	
	• Gear check				○	○	
Gear train	• Crank gear contact and pitting check			○	○	○	
	• Cam gear contact and pitting check			○	○	○	
	• Idle gear contact and pitting check			○	○	○	
	• Each pump driving gear contact and pitting check			○	○	○	
	• Each gear backlash check			○	○	○	
	• Idle gear bushing check					●	
Fuel control linkage	• Linkage looseness check	○	○	○	○	○	
	• Spring check			○	○	●	
	• Ball bearing and busing wear check			○	●	●	
	• Rack lever, reamer bolt, link wear check			○	○	●	
	• Link boll, rod end check			○	○	○	
	• Link pin check			○	○	●	
Turbocharger	• Disassembly, cleaning and check			○	○	○	Refer to the Instruction Manual for turbocharger
	• Bearing check			○	○	●	
Charge air cooler	• Cooling water passage cleaning			○	○	○	
	• Air passage cleaning			○	○	○	sea water cooling
	• Pressure test			○	○	○	system specification
	• Anti-corrosion zinc replace		●	●	●	●	

** Please refer to 7.3.3 Contents of daily check about pinion of air starter checking
*** Please refer to instruction manual of air starter. Overhaul can be dealt by maker or customer

○ : Check & Cleaning, △Partial Check & Cleaning
● : Replace

Inspection item	Contents of maintenance	B	C	D	E	F	Remarks
Exhaust manifold	• Expansion joint check		○	○	○	●	
	• Lagging check, repair		○	○	○	○	
	• Manifold inner surface check and cleaning				○	○	
Intake and exhaust Manifold, Intake duct	• Intake and exhaust manifold inner surface check and cleaning			○	○	○	
	• Intake duct crack check			○	○	○	
Air bypass and Waste gate system	• Linkage looseness check	○	○	○	○	○	
	• Expansion joint check		○	○	○	●	
	• Lagging check, repair		○	○	○	○	
	• Ball bearing wear check			○	●	●	
	• Lever, reamer bolt wear check			○	○	●	
	• Link ball check			○	○	●	
	• Butterfly valve check		○	○	○	●	
	• Air cylinder check	○	○	○	○	○	
Fuel oil feed pump	• Oil seal replace			●	●	●	In case of engine driven
	• Ball bearing check			○	●	●	
	• Coupling check			○	○	●	
Cooling water pump	• Oil seal replace			●	●	●	In case of engine driven
	• Mechanical seal replace			●	●	●	
	• Ball bearing check			○	●	●	
Cooling water pipe	• Flexible coupling replace				●	●	
Thermostat for cooling water	• Thermostat check, replace		○	○	●	●	
Cooling water cooler	• Cleaning and check			○	○	○	
Lubricating oil Pump	• Gear contact and pitting check				○	○	In case of engine driven
	• Bushing check				○	●	
Lubricating oil regulating valve	• Valve check and lapping			○	○	○	
	• Valve spring check			○	○	●	
Thermostat for lubricating oil	• Thermostat check, replace		○	○	●	●	
Lubricating oil cooler	• Cleaning and check			○	○	○	
Lubricating oil filter	• Automatic filter check			○	○	○	Refer to the Instruction Manual for lubricating oil filter
	• O-ring, seal replace			●	●	●	
	• Element check			○	○	●	

7.3.3 Contents of daily check

Inspection item	Contents of maintenance	Interval	Description
General item	・Each tank level check ・Each gauge indication check ・Each thermometer indication check ・Oil leak, water leak check ・Each part vibration check ・Each valve opening and closing check ・Each drain discharge ・Abnormal noise check	Every day Every day Every day Every day Every day Every day Every day Every day	Watch and record Record Record Watch Watch and touch
Fuel oil system	・Viscosity control ・Fuel oil drain quantity check ・Fuel oil temperature check	Every day Every day Every day	
Cooling water system	・Water quality analysis	500h	
Lubrication oil system	・Lubricating oil quality analysis ・Spot testing ・Sludge checker check	500h 500h Every day	
Starting air System Air starter	・Tightening check of pinion fitting nut On the air starter ・Checking the crack or abnormal wear of pinion gear surface of air starter	Half month Half month	Refer to the Instruction Manual of air starter
Turbocharger	・Sponge filter cleaning ・Blower washing ・Turbine washing	100h 500h 100h	Only case of filter silencer used
Engine mist	・Color and quantity check	Every day	
Exhaust gas	・Color and quantity check	Every day	Watch
Control system	・Grease up the Fuel control linkage, VIVT Tappet shaft drive unit, Air bypass and Waste gate system.	100h	

7.4 Daily check

(1) Check and record the oil levels of the following oil tanks and oil sumps to confirm the oil consumption, and add oil if necessary.

(a) Tank and oil sump oil level check

(a1) Lubricating oil sump tank

(a2) Reversing-reduction gear or reduction gear

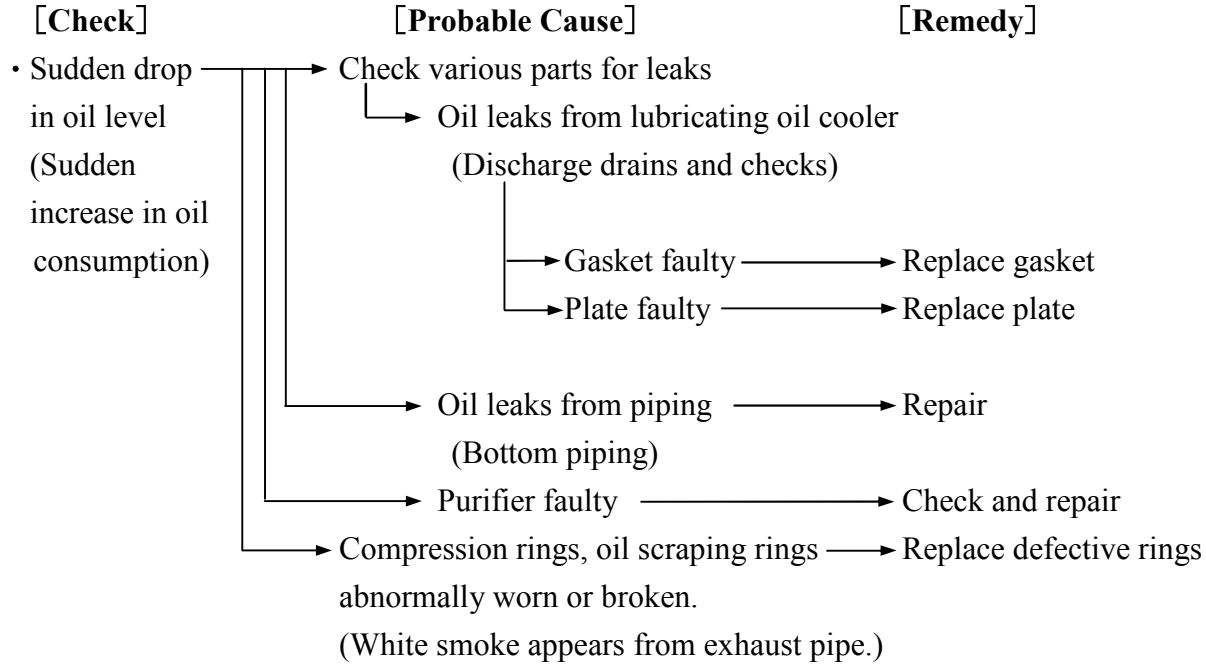
(a3) Stern bearings

(a4) Hydraulic governor

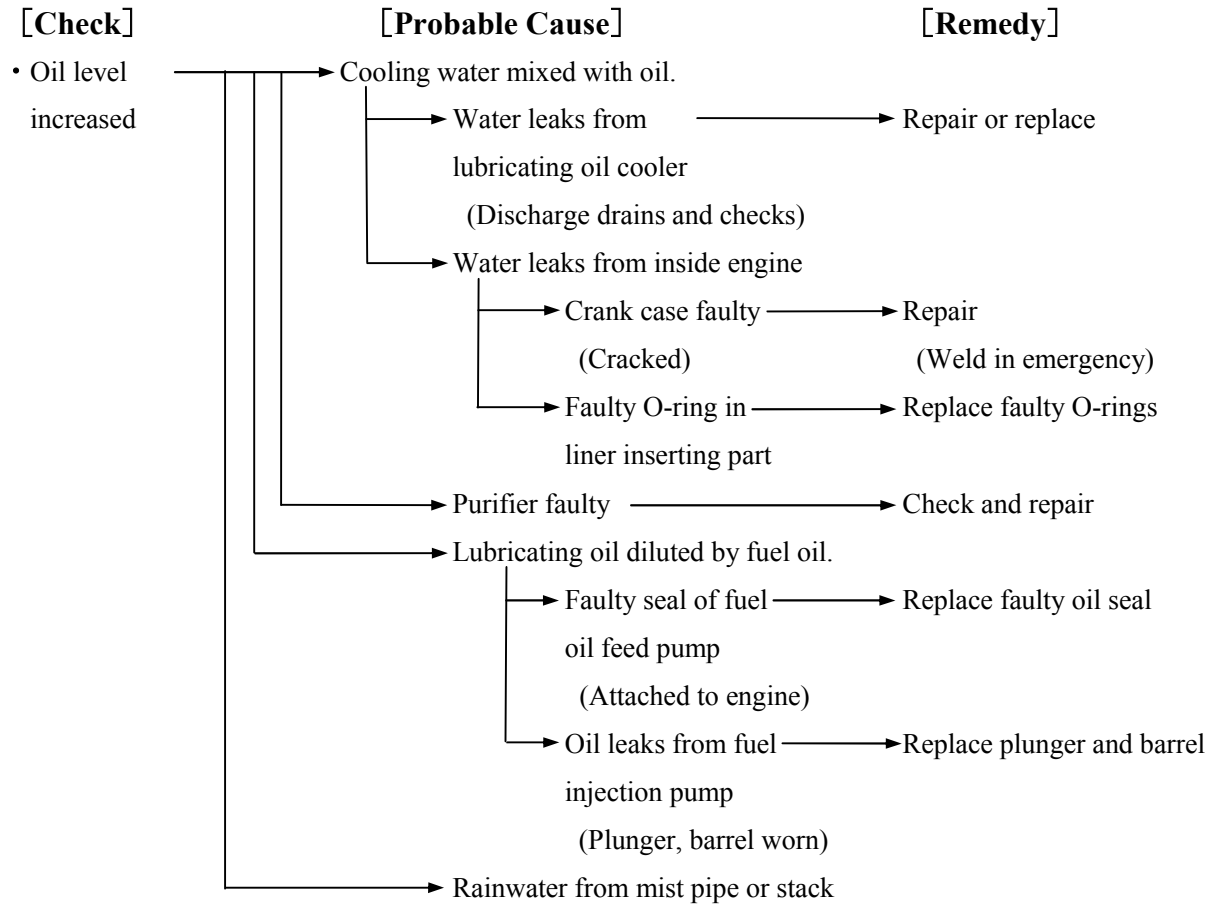
(a5) Oil cups and grease cups on engine

(b) Lubricating oil level check

(b1) System lubricating oil



NOTE : Lubricating oil Refer to **3.1.2**
When pouring lubricating oil in sump tank, don't pour huge lubricating oil at once. Sludge in the bottom of the tank soars and makes a filter be stopped up.


［Check］
［Probable Cause］
［Remedy］
・Oil level increased
Cooling water mixed with oil.
Water leaks from lubricating oil cooler (Discharge drains and checks)
Repair or replace
Water leaks from inside engine
Crank case faulty (Cracked)
Repair (Weld in emergency)
Faulty O-ring in liner inserting part
Replace faulty O-rings
Purifier faulty
Check and repair
Lubricating oil diluted by fuel oil.
Faulty seal of fuel oil feed pump (Attached to engine)
Replace faulty oil seal
Oil leaks from fuel injection pump (Plunger, barrel worn)
Replace plunger and barrel
Rainwater from mist pipe or stack

⚠CAUTION

Be especially careful to prevent water getting into the system lubricating oil because it can cause bearing seizure.

(2) Discharge drains from each tank and device

(a) Lubricating oil

・ Excessive water in drains → Water or rainwater leaks from Various parts → Refer to **7.4(1)**

(b) Fuel oil

・ Excessive water in drains
- → Fuel oil properties inappropriate → Analyze properties
- → Water entering from outside (From mist pipe, tank cover, etc) → Check and repair
- → Faulty purifier → Check and repair

・Excessive sludge in drains → Fuel oil properties inappropriate

・Foreign matter → Tank, pipes, devices not sufficiently cleaned

→ Analyze properties, operate Purifier continuously

(c) Starting air receiver

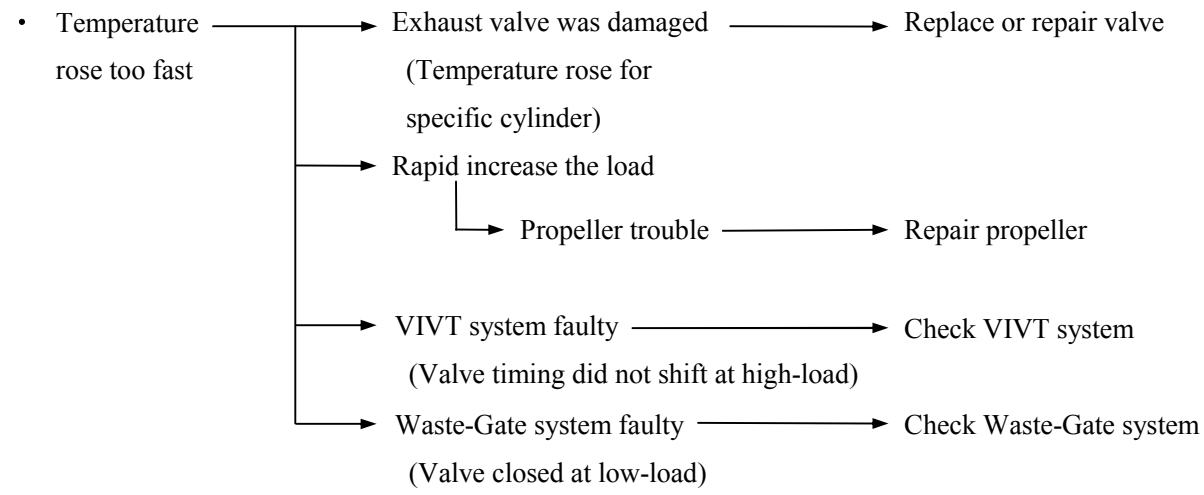
・Drains not discharged well → Inner drainpipe not properly positioned at tank bottom → Check inside from check door → repair

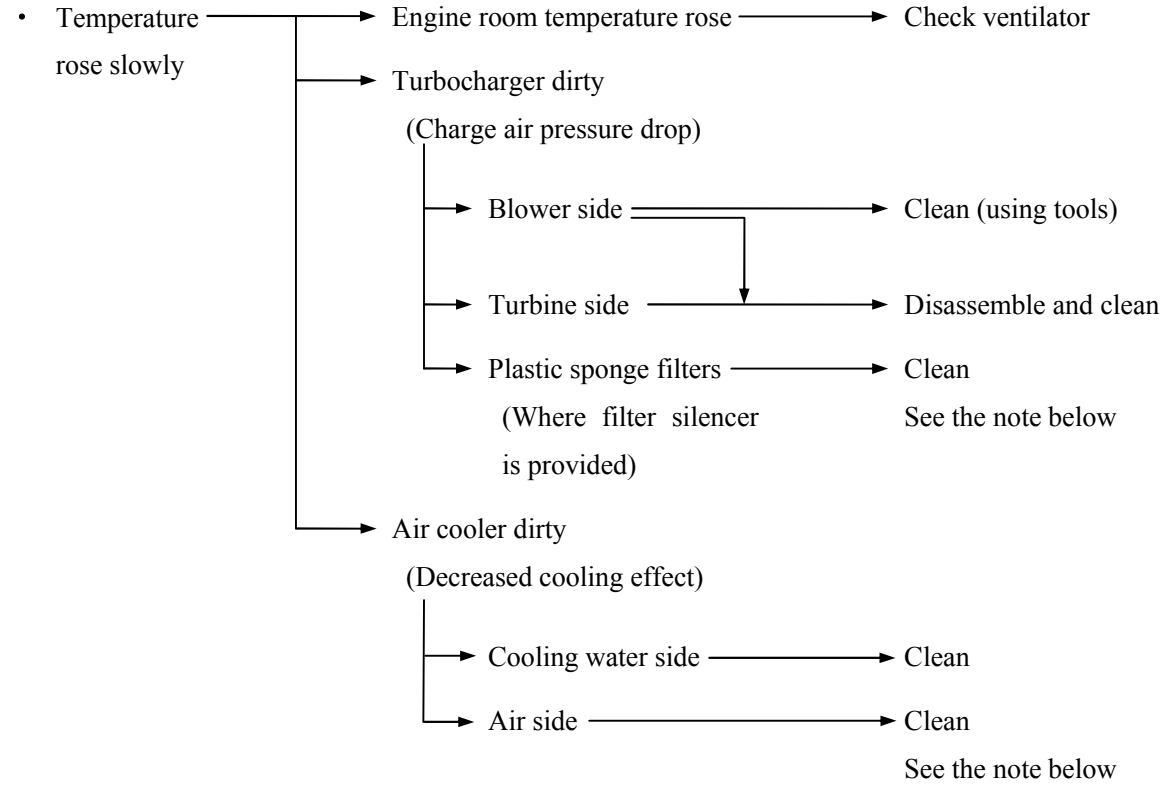
(3) Take engine performance data, and continually record data on shop trial, sea trial or local trial, and a maiden voyage. Items of data to be taken should be similar to those of the shop trial performance sheet. Pay particular attention to the following data.

(a) Performance analysis

［**Check**］ ［**Probable Cause**］ ［**Remedy**］

(a1) Exhaust gas temperature



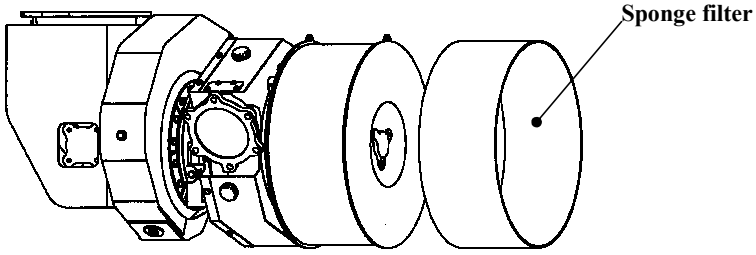


- Temperature dropped too low
  - → Imperfect combustion (Temperature dropped for specific cylinder)
    - → Check nozzle performance
    - → Check fuel injection pump rack scale
    - → Check fuel injection pump (Plunger stick)
  - → Intake and exhaust valve stick → Replace repair valves and valves guides
  - → Air-Bypass system faulty (Valve did not closed at high-load) → Check Air-Bypass system

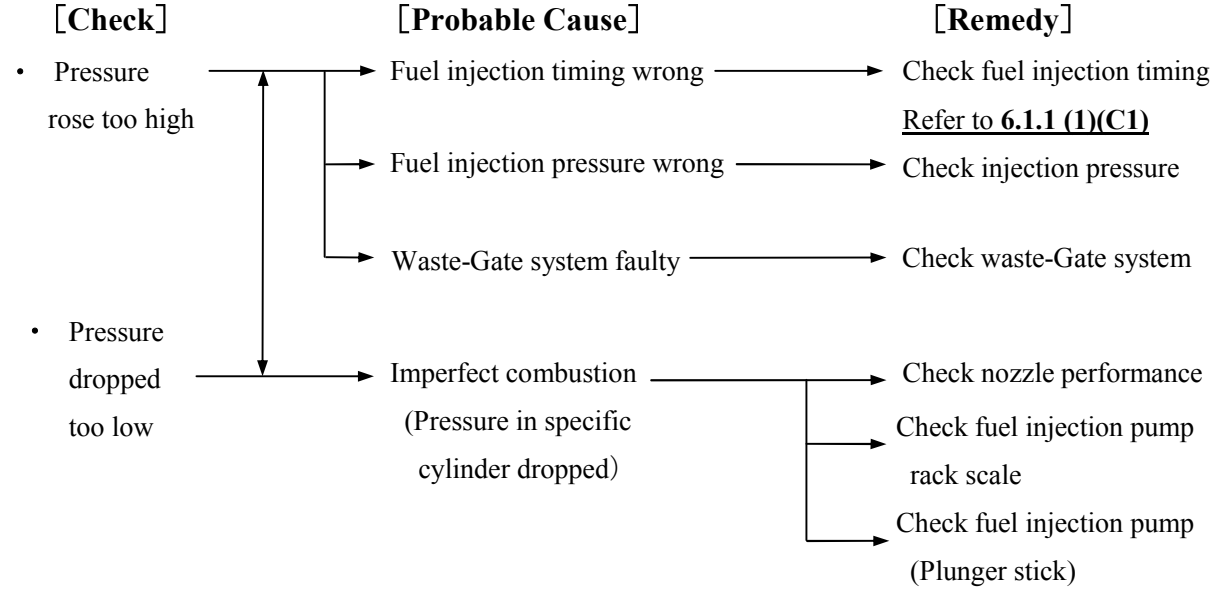
NOTE : (1) Clean the turbocharger's plastic sponge filter with neutral detergent, and dry it in the shade.
(2) The following detergent is recommended for cleaning the air cooler.
Supplier : IHI Power Systems Co., Ltd.
TEL : 0276-31-8271 (Customer support center)
Trade name : NIIGATA SUPER-CLEAN
(3) Exhaust gas temperature difference of less than 50℃
Temperature among the cylinders is permissible at the rated output power in terms of engine performance.

WARNING

In case of rising cylinder pressure abnormally.
There is a danger of scald caused by the cylinder safety valve operation.
Never approach the spouting vent.



(a2) Maximum cylinder pressure



NOTE : (1) Maximum cylinder pressure difference of less than 0.5MPa among the cylinders is permissible at the rated output power in teams of engine performance.
(2) Adjustment of exhaust gas temperature and maximum cylinder pressure. Exhaust gas temperature and maximum cylinder pressure vary in a correlated manner, and an overall judgment is required in adjusting them.
Whichever must be adjusted, checks as mentioned above, and then proceeds to the following adjustment procedure.

(b) Adjusting exhaust gas temperature and maximum cylinder pressure

(b1) Exhaust gas temperature adjustment

Regulate fuel injection quantity for each cylinder.

→ Move the fuel control lever pointer to position 100% load
- → Cylinder with high exhaust gas temperature → Move back rack scale
- → Cylinder with low exhaust gas temperature → Advance rack scale

- Refer to **6.1.1**(1)(C) for the method of adjustment
- After this adjustment, the rack scale difference among the cylinders must meet the following requirements.

When fuel control lever is at the
stop position (fuel cut off) ---------- 0±1 or less
during operation ---------- 3 or less

NOTE : (1) If the rack scale difference is great, there is the danger of the engine not stopping when the fuel control lever is moved back to the stop position.
(2) Ideally, the exhaust gas temperatures and fuel injection pump rack scales for all the cylinders should be uniform, but this is unlikely due to manufacturing errors. So adjust the exhaust gas temperatures difference and rack scale difference to less than ± 30°C of the average temperature and less than 3, respectively, at normal engine output power. Avoid adjusting only one of them, and leaving the other with great difference.

(b2) Maximum cylinder pressure adjustment

Adjust the fuel injection beginning timing for each cylinder.

→ Cylinder with maximum pressure too high → Delay injection beginning → Thicken shim

→ Cylinder with maximum pressure too low → Advance injection beginning → Thin shim

- Refer to **6.1.1(1)(C1)** for the method of adjustment.
- Checks before adjustment.

  Before adjusting the maximum cylinder pressure, carefully check the cause of its variation. Do not carelessly attempt an adjustment.

  ① Conduct an injection tests on the fuel injection valves, and make sure that they operate properly. For the method of adjustment, refer to **7.5.1(1)(d).**

  ② Check that the engine is not over-loaded.

  ③ Read and record the fuel injection beginning crank angles, and checks that it agrees, with the shop test performance sheet.

(4) Check the lubricating oil automatic filter

(a) Daily check

This lubricating oil filter is automatic backflushing type. So the filter elements are cleaned automatically. However daily check is necessary as follow.

① Check for the differential pressure indicator

As the contamination increase, differential pressure in the filter also increase.

If differential pressure indicator became red color sign, check the filter elements.

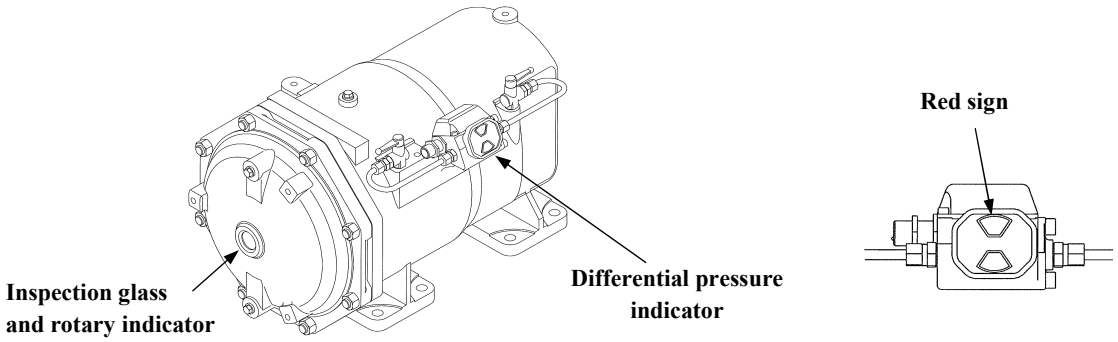
② Check for the rotating flushing arm

Check the rotating flushing arm (about 1 rotation/10sec) at the rotary indicator in the inspection glass.

③ Check for leakage

Check the leakage at connection of each filter.

NOTE : Refer to the Instruction Manual for the lubricating oil automatic filters.



(5) Check of Fuel oil filters

Clean the fuel oil filter

Determine the cleaning interval according to the condition.

If an automatic cleaning type is applied check its function being normal.

Refer to the Instruction manual for the filters.

(6) Check the combustion state

The fuel injectors must be checked whenever any of the following abnormalities is detected.

(a) Imperfect combustion → Dark smokes or sparks

→ Open the indicator cocks, and check which cylinder is faulty

(b) Maximum cylinder pressure drop

(c) Overheated fuel injection pump

(d) Cracked fuel injection pipe

(7) Check the lubricating oil

(a) Take sample (about 1 liter), have it analyzed by the oil supplier, and ask their advice on its usability.

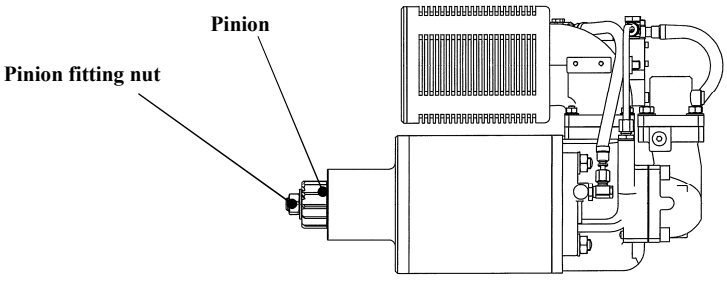
(b) The spot testing method is a simple way of testing the lubricating oil.

NOTE : Lubricating oil changing intervals vary with the fuel oil used and the conditions of use. The best way to determine when to change the lubricating oil is to analyze it.

(8) Check of air starter

(a) Inspect whether the pinion gear nut is not loosened.

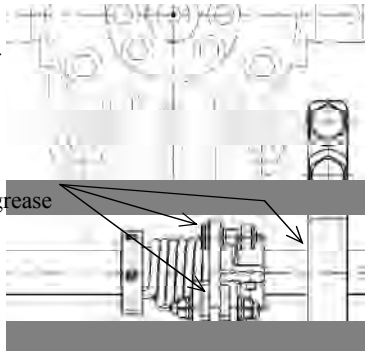
(b) Visually inspect the pinion gear and ring gear teeth for cracks and wear.



(9) Link parts of engine control system

Please lubricate to link parts and to bearings with oil or grease about below.

- Link parts of fuel oil control unit (layshaft)
- VIVT drive unit
- Link parts of air bypass and wastegate



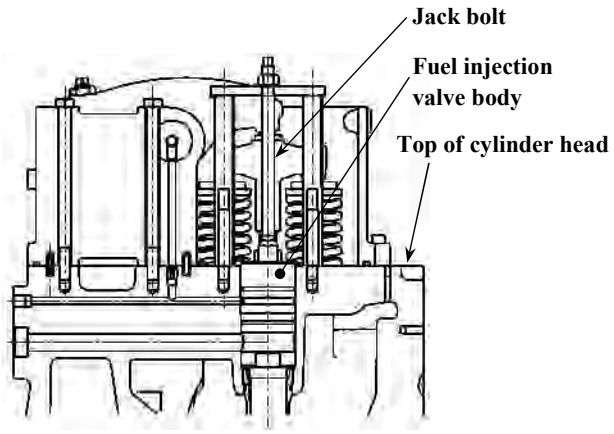
7.5 Check for each device

7.5.1 Cylinder head and around parts

(1) Check the fuel injectors

(a) Fuel injector removal procedure

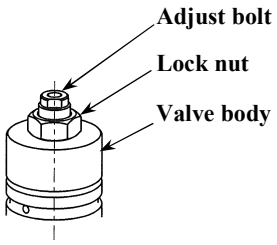
- Close the fuel oil main valve.
- Remove the cylinder head cover, fuel injection pipe.
- Remove the fuel injectors by using jack bolt.

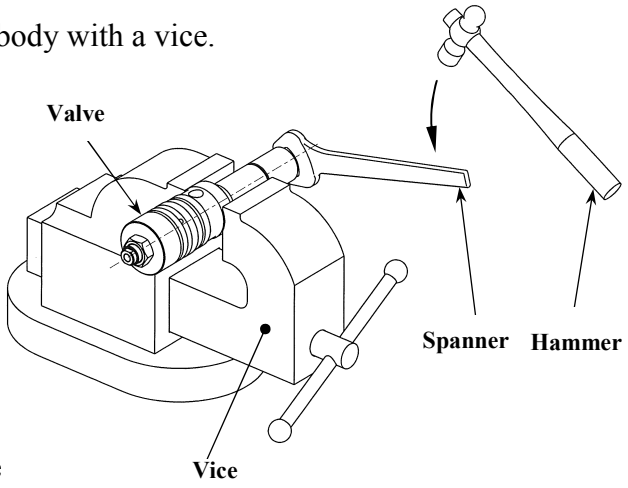


(b) Fuel injector disassembly and reassemble procedure

(b1) Disassembly

- Loosen the lock nut.
- Completely loosen the pressure adjust bolt.
- Lightly fasten the flanged part of the valve body with a vice.
- Loosen the nozzle nut.



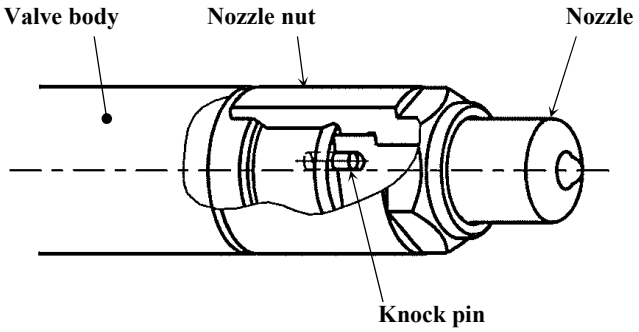


(b2) Fuel injection nozzle assembly procedure

Reassemble in the reverse procedure of disassembly.

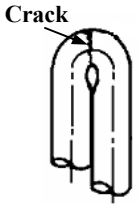
- Align the nozzle with the valve with the knock pin.
- Tighten the nozzle nut.

  -Refer to **5.2** Tightening Specification of Main Parts.
- After pressure adjustment, tighten the adjust bolt lock nut securely.



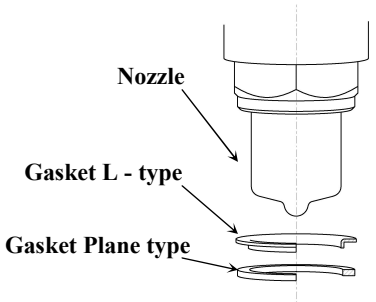
(b3) Fuel injector installation procedure

- Check the O-rings whenever the fuel injectors are disassembled.
  If that is damaged, deformed or hardened, change the O-ring.
  The O-ring hardened is cracked at bending 180°.
- If the fuel injector body appears rusty on the outside, remove the rust, and apply a suitable anti-corrosive.
  The following anti-corrosives are recommended.



Trade name: NIIGATA COAT 800
Agent: IHI Power Systems Co., Ltd.
Tel :+81-3-4366-1270 (Customer support center)

- Replace the gasket for seal.
- Clean the seat of the gasket of the cylinder head.
- Install the fuel injector into the cylinder heads.

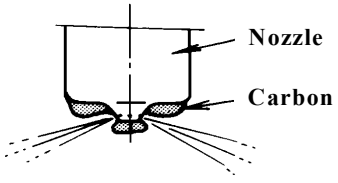


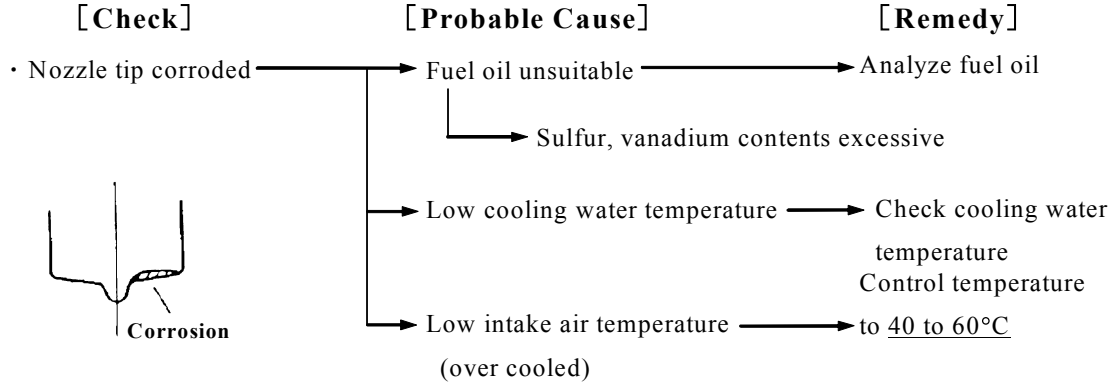
CAUTION : Be sure to replace the above-mentioned gasket whenever the fuel injectors are disassembled. The use of an imperfect gasket may cause carbon accumulation on the threaded parts of the nozzle nut, and make it too hard to turn.
And be sure to set gasket above-figure. Because this gasket has assembling order, assembling direction.

(c) Checks and remedies

(c1) External check

[Check]	[Probable Cause]	[Remedy]
• Excessive carbon deposits on nozzle tip. Some carbon deposits around injection hole (particularly around those of exhaust valves	Imperfect combustion	
	Fuel oil unsuitable	Analyze fuel oil
	Carbon residue excessive	
	Nozzle hole expanded	Change nozzle
	Low cooling water temperature	Check cooling water temperature
	Insufficient heating of fuel oil	Check fuel oil temperature

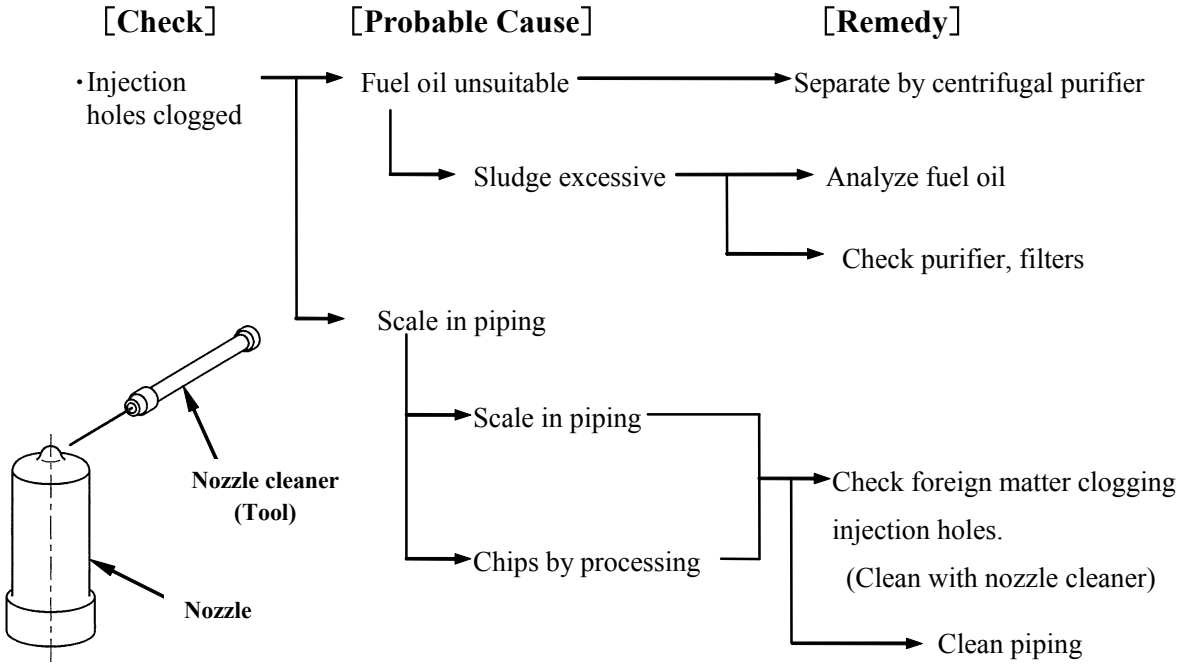




NOTE : (1) Exercise great care in handling the nozzle because they are precision-made parts.
- Be careful not to damage the seat and sliding parts.
- Keep parts immersed in fresh light oil to prevent rusting.
- Be careful of dust when reassembling.

(2) Be careful not to over-tightens the nozzle nuts. Otherwise, the nozzles will be deformed, causing the needles to stick.
(3) Nozzle performance and life depend largely on the properties of fuel oil. When using heavy fuel oil, exercise extra care in purity of the fuel oil and controlling the filters.

(c2) Injection hole check

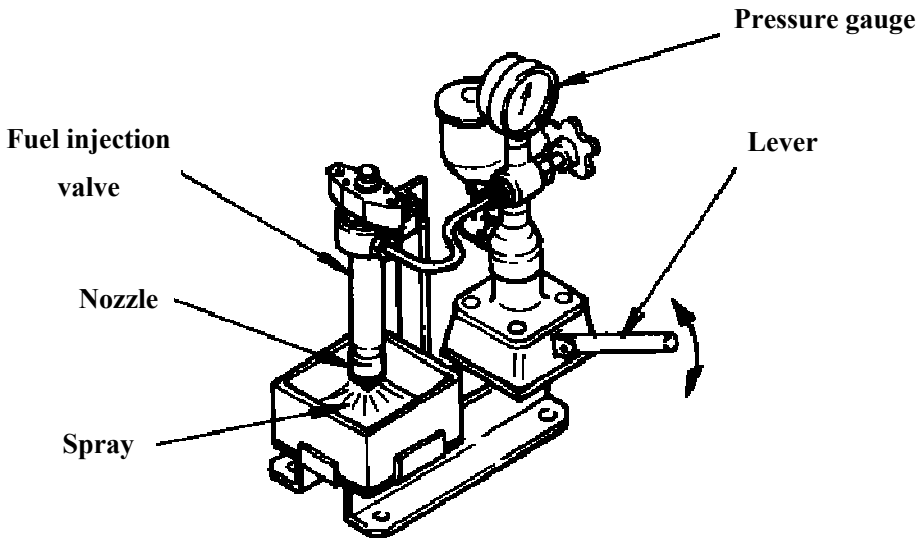


(c3) Fuel injection valve spring check ——→ If damaged, replace it

(d) Fuel injector test procedure

• Mount a fuel injection valve in the test pump.

Fuel Injector Tester



NOTE : First time injector testing must be performing within 500 hours because valve open pressure may be down for the first stage.

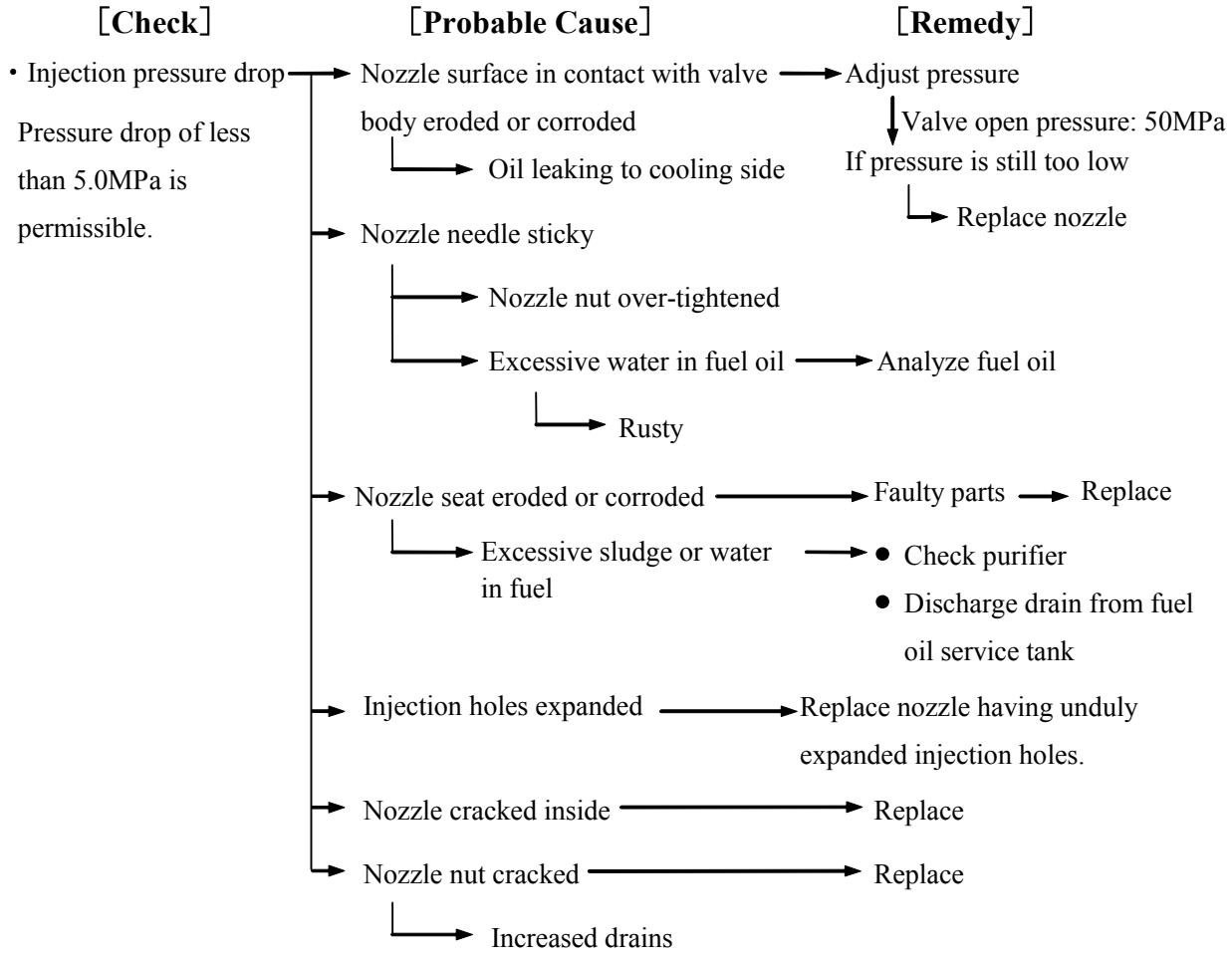
WARNIN

When perform injection test, if high-pressure oil spray touched the skin directly, should be damaged.
Do not bring hand or body near the oil spray area.
If oil spray enter into the body through the skin, consult a physician immediately.
Make sure carefully check the joint part of the fuel injector tester before rise up the hydraulic pressure.

CAUTION

Put on safety glasses when perform fuel injection testing.

(d1) Nozzle injection test by test pump



① Injection pressure check (Operate the pump lever slowly)

② Pressure holding check (Operate the pump lever slowly)
Good if pressure of anywhere 45～50MPa is kept after injection.

③ Spray check (Operate the pump lever as quickly as possible)
Good if fuel is completely sprayed uniformly from all injection holes.

④ Injection end check
Good if injection ends with a sharp injection sound without a fuel drip.
If all test results are good, the fuel injection valve can be used as it is.

If the test results are not good, take the following steps

- Disassemble and check nozzle → Refer to **7.5.1**(1)(C)
- Reassemble and test

<Nozzle assembly procedure>

- Locate the nozzle to the injector body by knock pin.
- Tighten the nozzle nut. → Refer to **5.2** Tightening Specification of Main Parts.
- Adjust the valve open pressure by test pump.
- Tighten the lock nut after adjusting.

→ Test at injection pressure 0MPa → Make sure that fuel is uniformly sprayed from all injection holes → Check that injection holes are normal

→ Gradually raise injection pressure.

Check minimum injection pressure at which the three factors in Item above, that is pressure holding, spray, and injection end, are satisfactory, and at which a Schnarr sound can be heard.

→ Good if minimum injection pressure is 18MPa or less.

If minimum injection pressure is more than 18MPa disassemble, repair, and test again.

→ If still not good, replace nozzle.

NOTE : The Schnarr sound is a soft of pulsating noise produced when the tester lever is pushed in slowly about 1 to 2 seconds after fuel has been fully injected by pushing the tester lever down quickly a few times. At this time, a pulsation can be felt through the lever.

(2) Cylinder head overhaul

(a) Prepare of cylinder head disassembly

Before cylinder head disassembly, it is necessary to discharge cooling water in cylinder head, liner ring, and intake and exhaust manifold.

(a1) Close the valves for the fresh water expansion tank connecting pipes.

(a2) Open the drain valves, and discharge the water.

(b) Cylinder head disassembly procedure

(b1) Remove following parts from them beforehand.

- Cylinder head cover
- Fuel oil pipe cover
- Exhaust manifold cover
- Rocker gears
- Fuel injector and injection pipe
- Fuel drain pipe
- Lubricating oil pipe
- Intake and exhaust push-rod

(b2) Loosen the cylinder head nuts with a hydraulic jack (tool).

Check for the following points before installing the hydraulic jack.

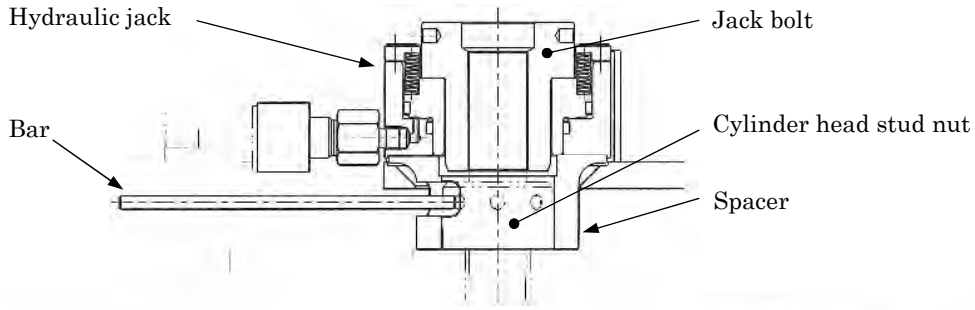
- Inspect the pressure gauge and hydraulic jack see if the hydraulic jack operates normally. Check the pressure gauge periodically to use the one that falls within the period of validity. (If pressure gauge is abnormal, clamping under the regular clamping force is impracticable.)
- Remove the rubber cap of cylinder head stud bolt and make sure that threads are kept clean.
- Clean up the topside of cylinder head and the underside of hydraulic jack so as to be free from foreign matter. (Use extreme care for the fact that inclusion of foreign matter may decrease the clamping force.)
- Apply the spray type MOLYKOTE to the threads of jack bolt**.**

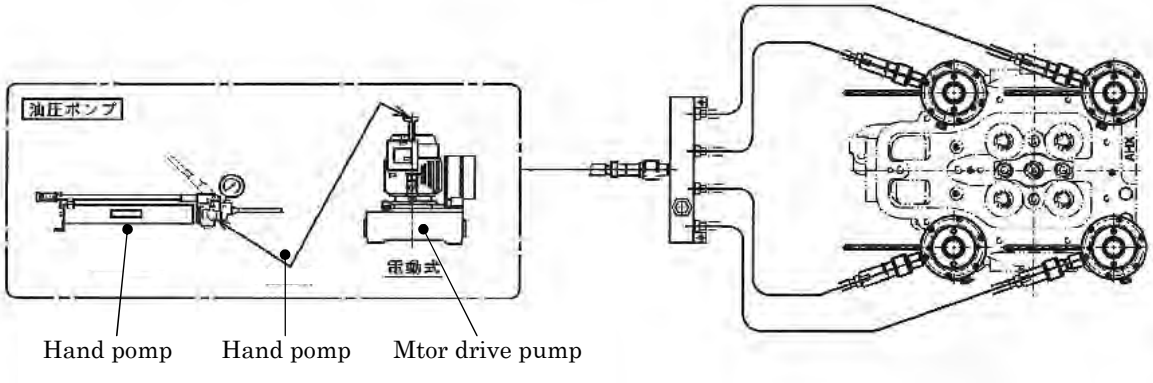
Hydraulic jack using method

- Set the hydraulic jack to the four cylinder head studs.
  In case of tightening by 2 studs, set the hydraulic jack to diagonally opposite cylinder head studs.
- By hand until the bottom has come in contact lightly with the head of cylinder head stud.
  Make sure the top of jack and the top of cylinder head are parallel.
  (The clearance between the cylinder head stud nut and the underside of jack bolt becomes approx. 6.5mm.)
  Loosen nut by a half revolution. (When conducting disassembly by the hydraulic jack, nut maybe locked by the shrinkage of jack bolt)
- Connect the hydraulic jack with high-pressure hose.
- With the check valve of hydraulic pump being put in working condition, operate the hydraulic pump to increase hydraulic pressure gradually.
- After increasing the hydraulic pressure up to the minimum pressure of 130MPa at which the cylinder head stud nut becomes loose, loosen the nut by the use of Turning rod.
- If it is prevented from loosening, increase the hydraulic pressure up to 135MPa .
- In this case, make sure that all of the 4-nuts become loose.
  If even any one of them does not become loose, decrease the hydraulic pressure and check for possible abnormality in the hydraulic jack and pressure gauge. (if hydraulic pressure is increased excessively, the seat surface may sink)

・Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Thread Size
Cylinder head stud	5mm	2 rotation and a half	M36×2





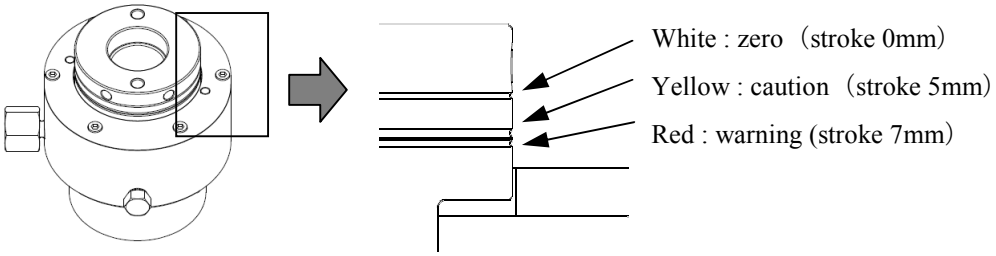
(Motor drive is option)

Cylinder head hydraulic jack

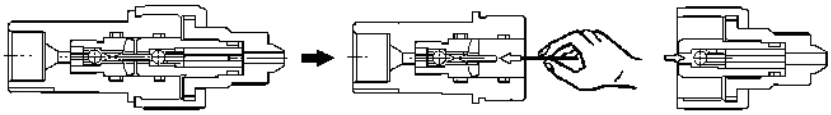
NOTES : (a) It is necessary to discharge the remained oil in the hydraulic jack because it makes bad operation of the hydraulic piston. Discharge the remained oil as the following procedure.

(a1) Connect the high pressure hose to the hydraulic jack.
(a2) Open the oil pump valve.
(a3) Tighten the jack bolt.

※ With the check valve of the hydraulic pump closed or without connecting the high pressure hose, even if it's tightened, the oil in the hydraulic jack won't drain and piston will not lower.
If oil remains in the hydraulic jack, the hydraulic jack may be broken due to over stroke during pressurization. Do not stroke over red warning line



(b) Existence of air in the hydraulic pressure may encounter difficulty in pressure increase. In such cases, loosen Couplers of high-pressure hose joint and remove the air by thrusting the check ball valve with a nail or the like.



(c) If the cylinder head stud nut is excessively returned in contact with jack bolt there is a possibility of the nut being locked. To prevent this, do not return the nut excessively. For the amount of returning the nut, refer to the following as a standard.

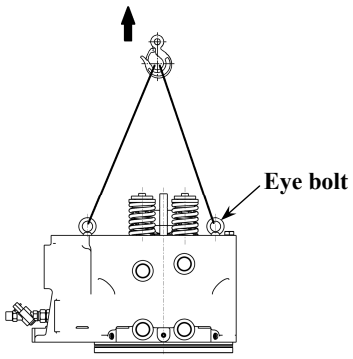
General Cautionary Instruction

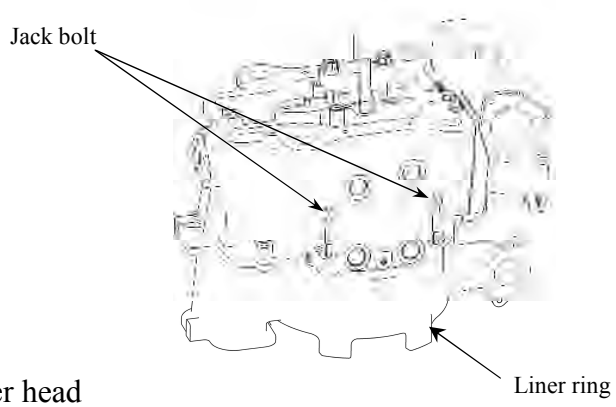
(1) To prevent the stud and nut threads of cylinder head from being damaged by denting etc., protect them with rubber caps unless they are put to use.
(2) When using the hydraulic jack, make sure that each joint is from oil leaks.
(3) During the hydraulic jack being in operation, do not gain access, closer them necessary to the high-pressure hose section for the sake of safety.
(4) periodically inspect each part of hydraulic pump.
Example)

High-pressure hose	-------	Occurrence of cracking, fissure, etc.
Hydraulic pump pressure gauge	---------	Periodically conduct inspection test or replacement. (At least once a year as a standard, and distinctly make the date of inspection and replacement on the pressure gauge.)
Various joints	---------	Occurrence of backlash and oil leaks.
Jack bolts	---------	Denting of threads.

•Lift up the cylinder head with eye-bolt.

※Separate cylinder head and liner ring by using jack bolt if liner ring is caught in cylinder head when cylinder head is lifted.





(c) Maintenance and checking for cylinder head

Remove the carbon perfectly before checking.

[Check]	[Probable Cause]	[Remedy]
(c1) Excessive carbon deposits	→ Fuel oil unsuitable	→ Analyze fuel oil

NOTE : Engines burning heavy fuel are liable to more carbon deposits, which are permissible, however, unless other parts are adversely affected.

(c2) White deposits excessive	→	Lubricating oil TBN unsuitable	→ Select lubricating oil with low TBN
(c3) Corroded	→	Cylinder overcooled	→ Enforce strict temperature control.

(c4) Make a dye check.

•Cracked →

- Cylinder overcooled (Temperature control faulty) → Enforce strict temperature control → Standard cylinder outlet temperature: 70°C to 80°C
  - Thermostat faulty → Replace element
- Maximum cylinder pressure too high → Adjust maximum pressure
- Cracked parts → Slightly cracked → Repair by grinding
  - Seriously cracked → Replace

NOTE : Contact our service station if find corroded parts and cracked parts.

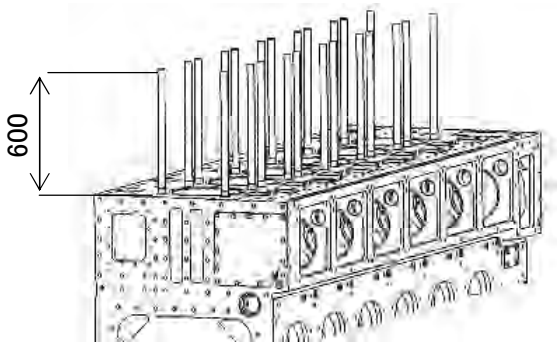
(d) Cylinder head reassembling

Reassembling is carried out in the reverse order to overhaul.

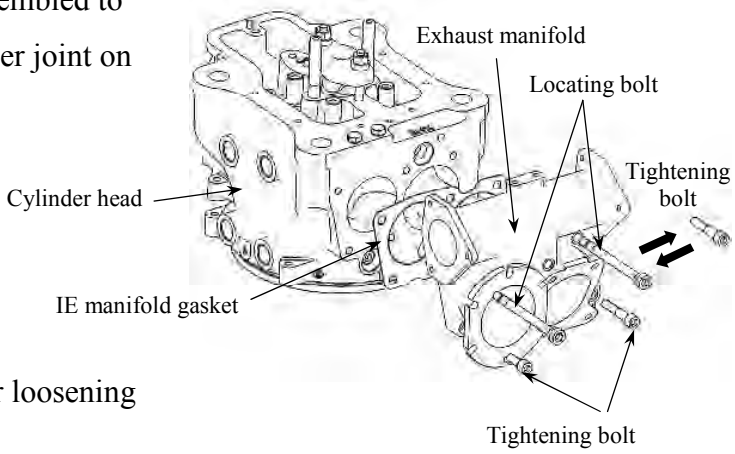
- Before mounting the cylinder head, carry out cleaning of the threads of cylinder head stud and also cleaning of the topside of cylinder head.

  (Take remedies beforehand against the tear, impression etc, of the mating surface of cylinder stud nut.)

- All gaskets of cylinder head should be replaced every disassembly.
- Tip of cylinder head stud should be 600 mm ±1 from top of cylinder brock.



※Decide the position of intake & exhaust manifold with using locating bolt at upper double side when it is assembled to cylinder head. And replace rubber joint on cooling water channel.



-Primary tightening

Tightening the nuts by hand after loosening the nuts.

-Intermediate tightening

Increase the hydraulic pressure up to 65MPa and turn the nut by Nut turning rod to tighten the nut so as to come in close contact securely with the bearing surface of cylinder head. Thereafter, open the check valve of hydraulic pump to return the hydraulic pressure to approx. 5MPa and make sure that the nut is in close contact with the bearing surface of cylinder head. (There is a possibility that the jack may be caused to move when hydraulic pressure is returned to as low as 0MPa.)

-Final tightening

Close the check valve of hydraulic pump to increase the hydraulic pressure up to 130MPa and tighten the nut by Nut turning rod.

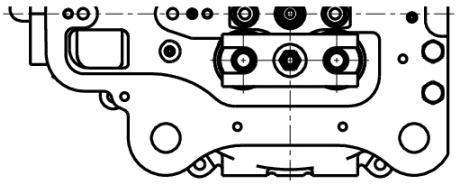
-In case of tightening by two studs

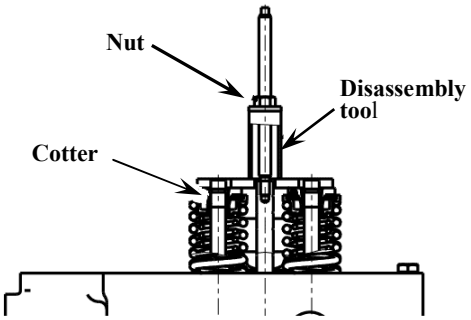
Tighten the diagonally opposite cylinder head stud nuts as intermediate tightening.
Then tighten the remaining two stud nuts equally.
After that tighten the two each stud nuts to final tightening.

(3) Exhaust valves and exhaust valve seat check

(a) Intake valve and exhaust valve disassembly procedur

- Remove the intake and exhaust valve rocker gears assembly.
- Attach the tool (spring remover).
- Tighten the nut, and remove cotter.





⚠ CAUTION
When disassemble the spring part, care must be taken not to damage with jumping part.

(a1)Checking exhaust valves and exhaust seats.

[Check]	[Probable Cause]	[Remedy]
•Carbon deposits excessive	Fuel oil unsuitable (Carbon residue or ash content excessive)	Analyze fuel oil
	Fuel injector not operating properly	Test fuel injector
•Valve seat damaged	Exhaust gas temperature too high	Grind or lap seat
	Valve rotator faulty	Replace
	Fuel oil unsuitable → Sulfur Vanadium Sodium Contents Excessive	Analyze fuel oil
•Valves and valve seats corroded		Replace if seriously corroded

(a2) Make a dye check exhaust valve stem → Replace if cracked

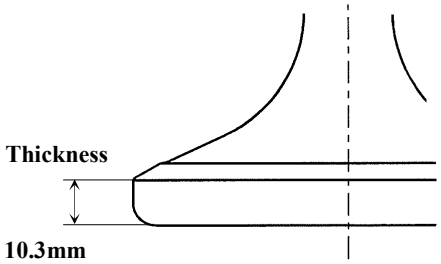
(a3) Measure the valve stem bend and diameter → Replace if over-limit

Refer to Paragraph **5.1** Parts Adjust Standers

(a4) Valve spring check → Replace if damaged

(b) Lathing or grinding exhaust valves and exhaust valve seat

(b1) Check the thickness of the bottom end of the valve, and see that the seat reinforcement has enough allowance for correction



(b2) Exhaust valve stem and seat correction

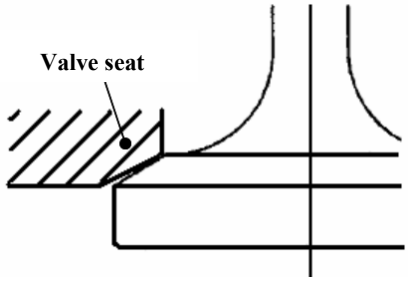
Correct the exhaust valve and exhaust valve seat only when correction is really necessary. Excessive correction thins the seat reinforcement, and thus shortens the lives of the valve and exhaust valve seat. After several hundred hours of operation, the valves and valve seats develop a pattern, which gives a misleading impression, as the valves and valve seats with such a pattern are still usable for quite a long time. The pattern on the seats is very fine, and hardly poses problems. Be careful not to unduly correct the seats having such a pattern because it can rather worsen them.

(b3) Hang a tool on the ditch in the upper part of the exhaust valve seat, and pull it out. Confirm whether to cause corrosion etc. in the exhaust valve seat and cylinder head. When the exhaust valve seat is assembled again, put dry ice into alcohol, place a new exhaust valve seat into it, to cooling in beginning.(Refer to**7.5.1(4)(C)**) In that case, do not put it in the O-ring part to prevent stiffening by cooling the O-ring. Next, the cooled exhaust valve seat is built into the cylinder head so as not to do damage O-ring. When it returned normal temperature, fit it securely into place by striking it with hummer. In that case, use a pad so as not to damage the exhaust valve seat by striking it.

Valve Seats Where Correction Is Required

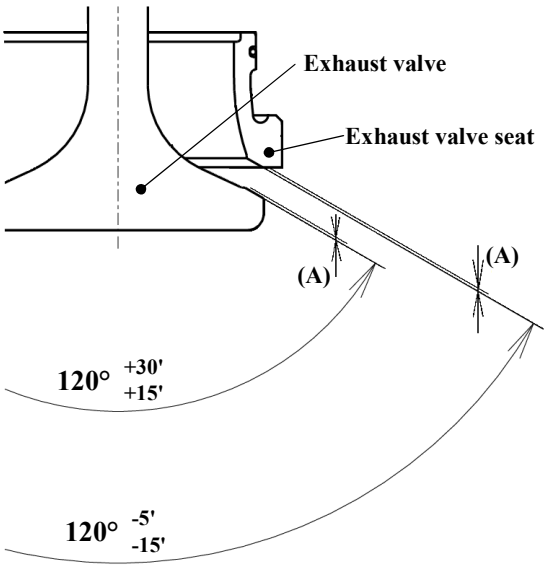
Correct the valve seats in any of the following cases.

- With the valve pushed to the valve seat by hand, a clearance gauge of 0.04 mm can be inserted between seat and valve.
- The valve and valve seat contact each other along the inner edge (As shown below).
- The seat is dented, burnt, or otherwise damaged.
  - If serious damage is found, or if the seat is cracked, the seat cannot be repaired for reuse.



(b4) Lathing seats

Lathe the exhaust valve to 120°(+15′~ +30′) and the exhaust valve seat to 120°(-5′~ -15′) as shown below. Use a lathe, avoid a grinding machine due to the cause of reinforcement cracking. Finish the surface like the mirror.



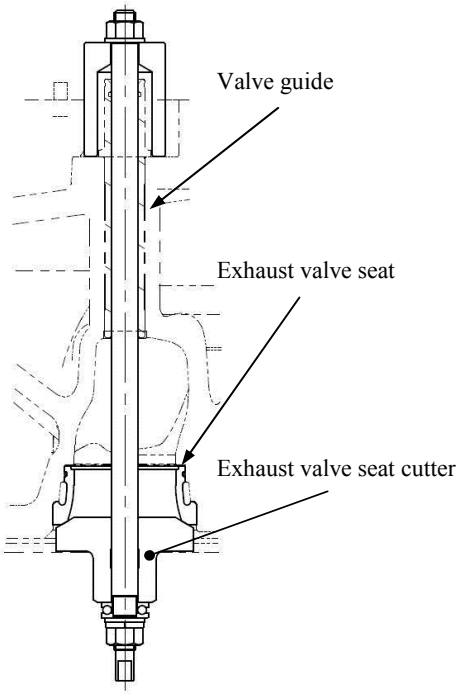
Correct limit (A)=1.5mm

NOTE : Observe the following conditions when lathing the exhaust valve seats.		
	Exhaust valve	Exhaust valve seat
Material in seat	NIMONIC	STELLITE No.6
Cutting speed min^{-1}	100 to 130	100 to 130
Feed mm/rev	0.1~0.12	
Cutting tool	JIS K10 or HTi 10 made by Mitsubishi Materials	

(b5) Seat contact check

Check seat contact after lathing or lapping the exhaust valves and exhaust valve seats. Make sure that the seats uniformly contact the peripheral edge or about 1/2 to 2/3 of the contact surface from the peripheral edge.

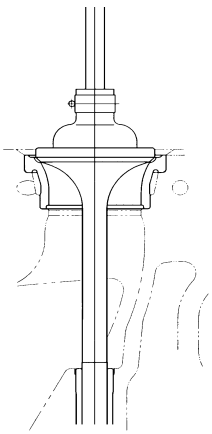
(b6) Correct exhaust valve seat by using exhaust valve seat cutter (seat cutter is option)



NOTES : If exhaust seat cutter is used for correcting valve seat, please check wear of valve guide at first because it may not correct eat accurately. If the valve guide is getting wear down, please replace it to new one.

(b7) Exhaust valve lapping procedure

- Set the valve to lapping tool.
- Coarse lapping
  Use carborundum No. 150. Hold the tool handle, and rotate it pressing below.
- Intermediate lapping
  Use chromium oxide powder
- Finish lapping
  Use seed oil for lapping

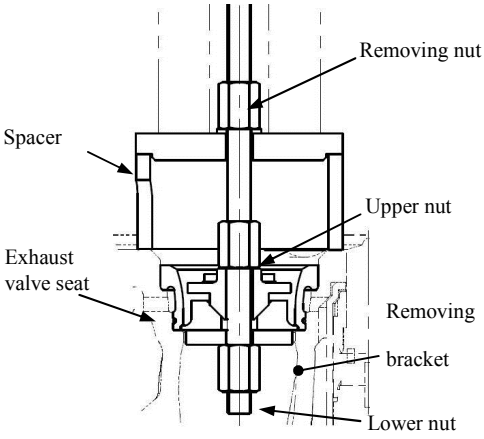


Valve Seat Lapping Method

NOTES : (1) Be careful not to use mineral oil together with carborundum or chromium oxide because it tends to produce scratches.
(2) Continue each lapping until the seat face has a complete fit. Finish lapping, in particular, must make the seat face like a mirror.

(c) Exhaust valve seat exchanging procedure

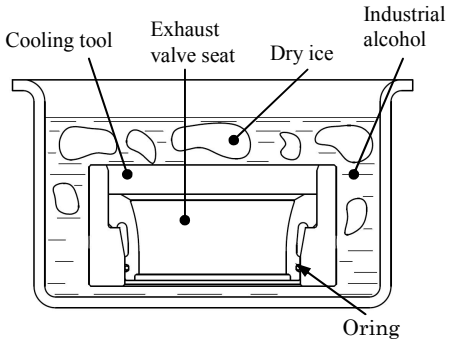
If the exhaust valve seat is worn down very much, please replace it following below.



Exhaust valve seat disassembly tool

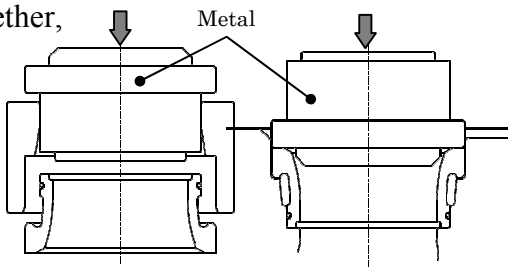
How to remove the exhaust valve seat
(Removing and inserting tool are option)

- Please set the removing bracket to the groove of upper part of exhaust valve seat.
  Get rid of carbon before attaching bracket if there is carbon in groove.
- Please tightening nuts, up and down side, and check whether it's fixing bracket tightly.
- Please set spacer and tighten removing nut with molykote.
- Exhaust valve seat will come out while nut is tighten.



How to insert the exhaust valve seat
(Removing and inserting tool are option)

- Please set new valve seat with new o-ring to cooling tool.
- Put liquid nitrogen or industrial alcohol and dry ice in a container, and put a valve seat with cooling tool together, cooling needs for 20 minutes
- Remove seat valve from cooling tool and insert to cylinder head with taking care not to get hurt.
- When the valve set returns to normal temperature, insert it surely by using hummer with a metal seat not to hurt seat valve.



Removing cooling tool

Inserting to cylinder head

⚠ CAUTION

Please take care of handling for cooling liquid or valve seat because those are quite low temperature. Please use glove certainly.

(d) Exhaust valve guide check

The exhaust valve guide is driven into the cylinder head. Measure its inside diameter as it is. If the inside diameter measurements taken at the top and bottom of the exhaust valve guide exceed the permissible limit, replace the valve guide.

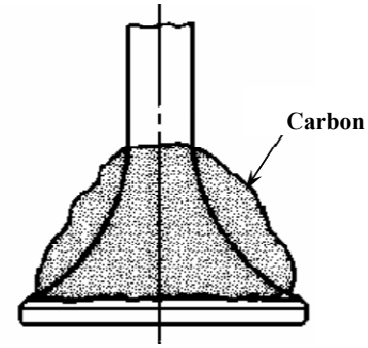
-Refer to Paragraph **5.1** Parts Adjust Standards

NOTE : If the valve guide is very worn, gas leakage from the guide increases and simultaneously causes uneven wear to the valve seat and adversely affects valve durability.

(4) Intake valve and intake valve seat check

(a) Intake valve and intake valve seat check

[Check]	[Probable Cause]	[Remedy]
(a1) Carbon deposits on back of valve	Intake valve guide worn	Replace intake valve guide
	Clearance excessive	
	Rocker gears lubricating oil drop	
	Low load operation long time	Prohibited



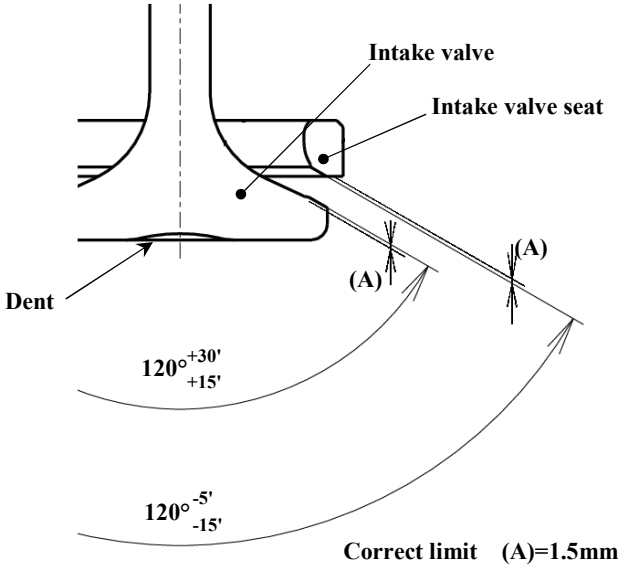
(a2) Seat face roughs		Lathe or lap seats.
Seat face irregularly	Intake air overcooled	
	Water condensation	Intake air temperature control: 40 to 60°C

NOTE : Intake valve sheet abrasion depends on the water condensation in the charge air. Check the air cooler outlet drain quantity. If the quantity is excessive , control water quantity , keep inlet air temperature 40~60°C.

(a3) Make a dye check intake valve stem	Replace if cracked
(a4) Measure the valve stem bend and diameter	Replace if over-limit Refer to Paragraph **5.1** Parts Adjust Standards
(a5) Measure the valve guide inner diameter	Replace if over-limit Refer to Paragraph **5.1** Parts Adjust Standards
(a6) Valve spring check	Replace if damaged

(b)Intake valve and intake valve seat lathing and lapping procedure

(b1)Intake valve and intake valve seat lathing ⟶ In case of damaged seat surface



NOTE : Be careful when valve assemble, the seat angle same as exhaust valve.
It possible to distinguish intake and exhaust valve, check the distinct dent at the center of valve .

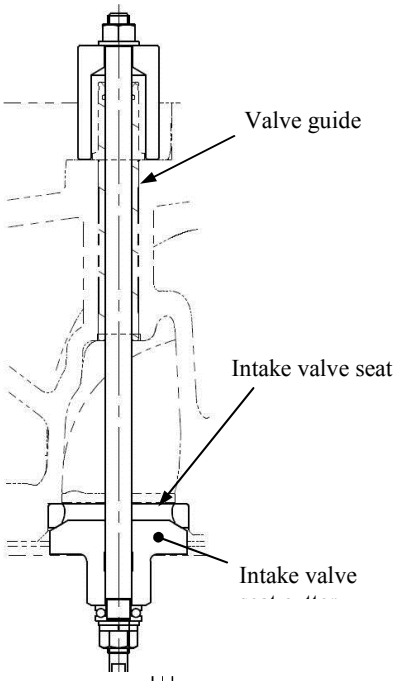
NOTE : Observe the following conditions when lathing the intake valve seats.		
	Intake valve	Intake valve seat
Material in seat	heat-resistant cast iron	STELLITE No.6
Cutting speed min^{-1}	xxx ~ xxx	100 ~ 130
Feed mm/rev	0.1 ~ 0.12	0.1 ~ 0.12
Cutting tool	JIS K10 or HTi20 made by Mitsubishi Materials	Igetalloy H2 made by Sumitomo Metal or H10 made by Mitsubishi Materials

(b2) Seat contact check

Check seat contact after lathing or lapping the intake valves and intake valve seats. Make sure that the seats uniformly contact the peripheral edge or about 1/2 to 2/3 of the contact surface from the peripheral edge.

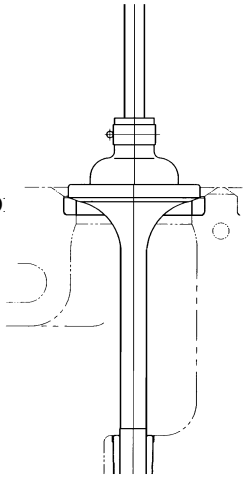
(b2) Correct intake valve seat by using intake valve seat cutter
(seat cutter is option)

NOTES : If intake seat cutter is used for correcting intake valve seat, please check wear of valve guide at first because it may not correct eat accurately. If the valve guide is getting wear down, please replace it to new one.



(b3) Intake valve lapping procedure

- Set the valve to lapping tool.
- Coarse lapping
  Use carborundum No. 150. Hold the tool handle, and rotate it p
- Intermediate lapping
  Use chromium oxide powder
- Finish lapping
  Use seed oil for lapping

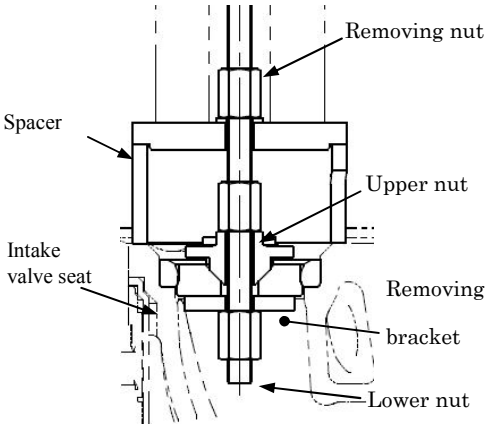


Intake Valve Seat Lapping Method

NOTES : (1) Be careful not to use mineral oil together with carborundum or chromium oxide because it tends to produce scratches.
(2) Continue each lapping until the seat face has a complete fit. Finish lapping, in particular, must make the seat face like a mirror.

(c) Intake valve seats exchanging procedure

If the intake valve seat is worn down very much, please replace it following below.

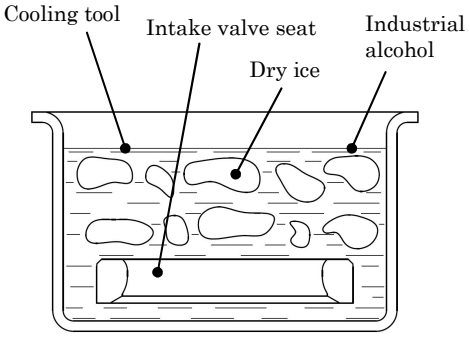


Intake valve seat disassembly tool

How to remove the intake valve seat

(Removing and inserting tool are option)

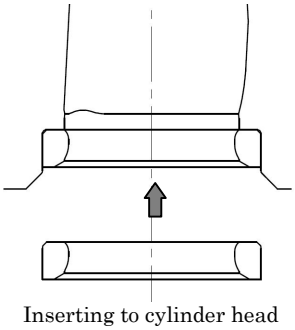
- Please set the removing bracket to the groove of upper part of intake valve seat.
  Get rid of carbon before attaching bracket if there is carbon in groove.
- Please tightening nuts, up and down side, and check whether it's fixing bracket tightly.
- Please set spacer and tighten removing nut with molykote.
- Intake valve seat will come out while nut is tighten.



How to insert the intake valve seat

(Removing and inserting tool are option)

- Please set new valve seat with new o-ring to cooling tool.
- Put liquid nitrogen or industrial alcohol and dry ice in a container, and put a valve seat with cooling tool together, cooling needs for 20 minutes
- Remove seat valve from cooling tool and insert to cylinder head with taking care not to get hurt.
- When the valve set returns to normal temperature, insert it surely by using hummer with a metal seat not to hurt seat valve.



Inserting to cylinder head

⚠ CAUTION
Please take care of handling for cooling liquid or valve seat because those are quite low temperature. Please use glove certainly.

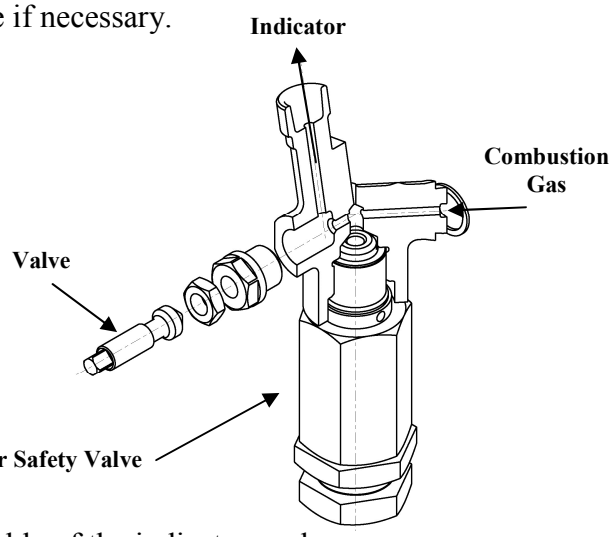
(d) Intake valve assembling procedure

Use the same tools as used for disassembly, and reverse the disassembly procedure.

(5) Intake and exhaust valve rotator check

Check the valve rotators for rotation, and replace if necessary.

(6) Indicator cock check



(a) Mounting and reassemble of the indicator cock

Must stop the engine when Mounting or reassemble of the indicator cock.

(b) Indicator cock check

- Indicator cock seat check.
- Indicator cock seat lapping. ⟶ Replace if damaged.

⚠ CAUTION
(1) Installation and disassembly may only be done on switched-off engine.
(2) Even on a switched-off engine the parts can be very hot for reasonable period of time. Wear protective gloves.

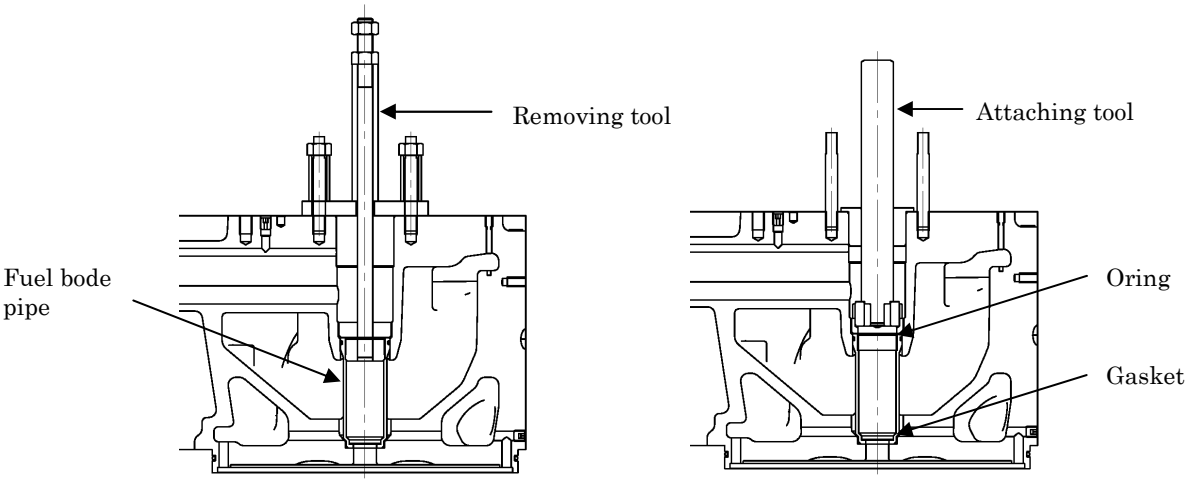
(7) Fuel valve body pipe check(Removing tool and Attaching tool are option)

(a) Fuel valve body pipe removal

- Remove the fuel vale body pipe
- Replace the O-ring and gasket.

(b) Fuel valve body pipe attachment

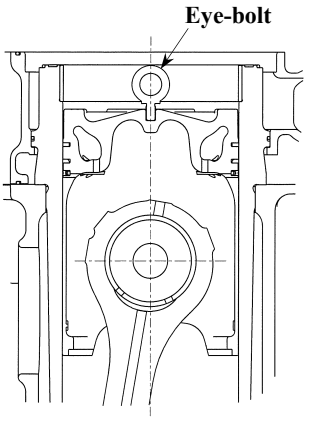
- Replace Oring and gasket
- Attach the pipe by using attaching tool



Removing Attaching

7.5.2 Piston, connecting rod check

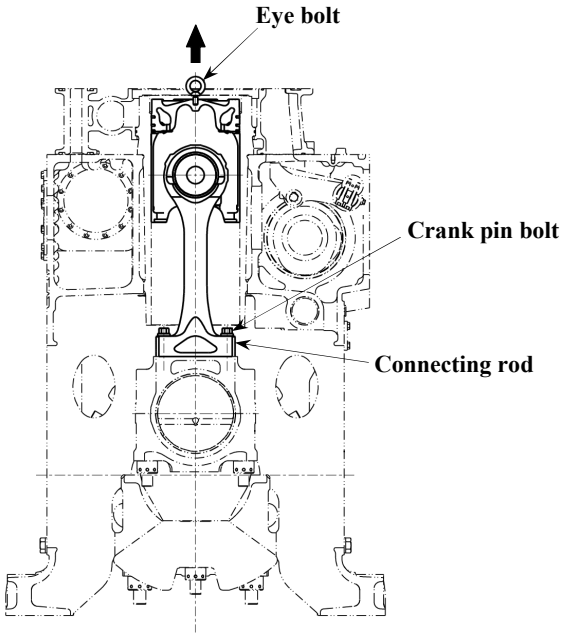
(a) Piston and connecting rod removal



(a1) Preparations for removing piston and connecting rod

- Remove the cylinder heads --- Refer to **7.5.1 (2)**
- Remove the fire ring. --- Refer to **7.5.3 (1)**
- Turn the crankshaft until a piston comes to 40° before top dead center, and stuff grease between the piston and liner.
- Thoroughly remove carbon from the tops of the liners in which the pistons do not slide. Exercise care not to damage the liners or touch the sliding face.
- The above steps are preparations for smooth removal of the pistons from the cylinder liners.
- Clean the tapped hole for lifting tool in the top of the piston heads, using a tap.
  - Screw size : M16×2.0 (pitch)
- Set a eye-bolt to the cleaned screw holes.

(a2) Piston and Connecting rod cap removal procedure



- Set the socket and the ratchet handle from the crankcase door
- Loosen the crank pin bolts.
  At this time, the bolts are temporarily tightened in the extent that can be turned by the hand.
- Turn and adjust the piston to the top dead center**.**
- Remove the crank pin bolts.
- Pull out the piston and the connecting rod gradually.

It is dangerous to rotate the big end cap when crank pin bolts are removed.
Be careful to pull out connecting rod.

(b) Connecting rod big end cap removal procedure

- **T**urn the crankshaft, the crank pin set to the 90° before top dead center position.
- Install the guide rail bracket ① in the crankcase door on both side.
- Install the guide rail ② in the crankcase, and fix to the guide rail bracket ①.
- Loosen the crank pin stud nuts by hydraulic jack.

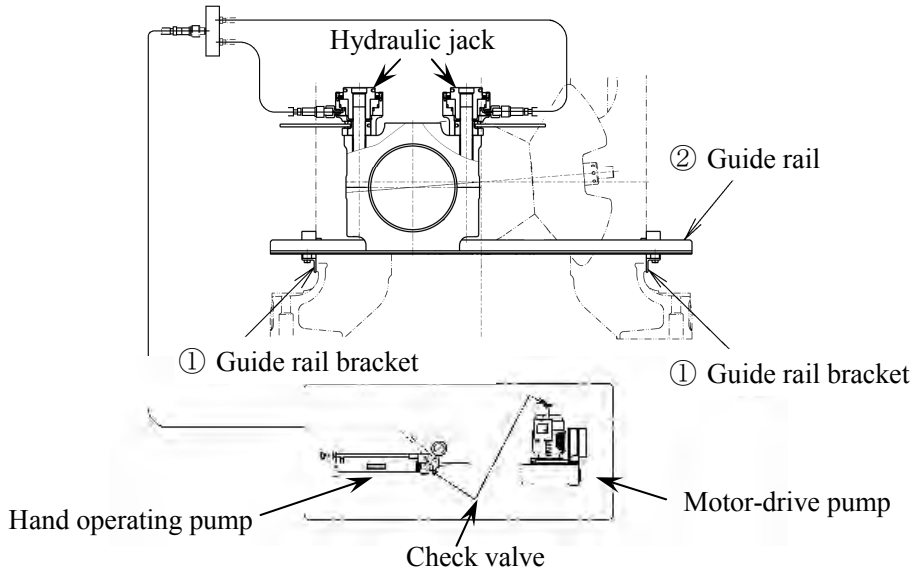
(b1) Big end cap put on the guide rail. At this point, set the crank pin stud nut to upper.

(b2) Set the two hydraulic jacks to crank pin stud nut.

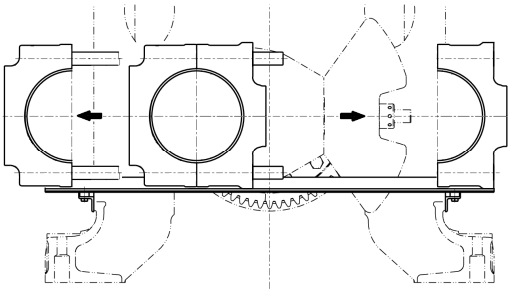
(b3) Loosen the crank pin nut. At this time, the nut is temporarily tightened in the extent that can be turned by the hand.

- Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Threads Size
Connecting rod	2mm	1 rotation	M36×2



- Make the connecting rod big end horizontal. The big end cap put on the guide rail and remove the nuts.
- Separate the end cap and pull out from the cylinder block.



＊ Reassembly procedure

Assembly procedure is carry out in the reverse order to disassembly procedure.

The mark of crank pin and stud nut fit securely.

(c) Piston check

(c1) Pistons

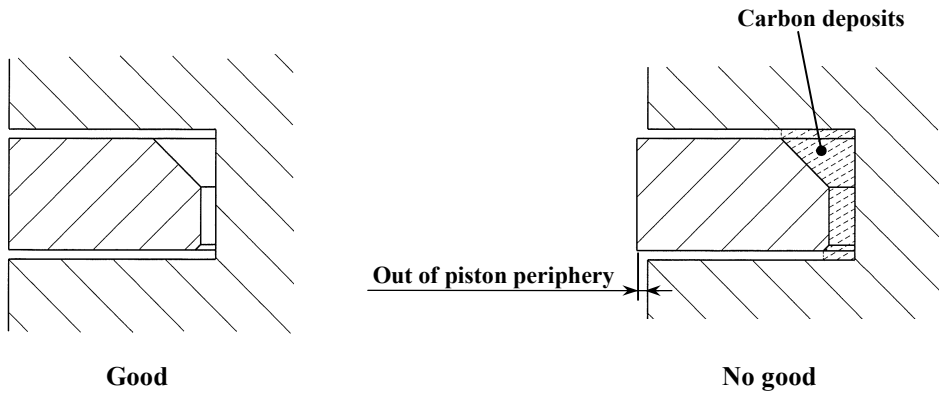
[Check]	[Probable Cause]	[Remedy]
• Excessive carbon deposits on surface	Fuel oil unsuitable → Carbon residue excessive	→ Analyze fuel oil
	Imperfect combustion → Fuel injection valve faulty	→ Test fuel injectors
• Excessive white deposits	Lubricating oil T.B.N. unsuitable	→ Use lubricating oil with low T. B. N
	Lubricating oil consumption too much	→ Consumption measures

(c2) Piston ring check

- Check the piston rings for stains and stickiness.

  Piston rings that have an appropriate amount of lubricating oil and that move freely are normal.

  If carbon deposits in the gaps between the piston rings and ring grooves make the rings stick or hard to move, it is abnormal. If this is the case, the rings might be out of the piston periphery.



Carbon Deposits in Ring Groove Clearances

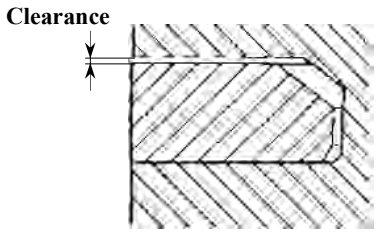
[Check] **[Probable Cause]** **[Remedy]**

- Ring groove dirty or worn → Oil rings faulty → Measure rings and ring grooves or worn → Refer to **5.1** Adjustment Standards for main parts Replace if necessary
- Lubricating oil deteriorated → Analyze lubricating oil → Change lubricating oil if analysis results require it

- Measuring ring dimensions
  It is necessary to measure all the rings.
  (No.1 and No.2 compression rings and the oil ring.)

Measuring Ring Groove Clearance

With clearance gauges, measure the clearances between the piston rings (No. 1 and No. 2 compression rings, and the oil ring) and the piston ring grooves at several points of the circumference and records the measurements.



[Check] **[Probable Cause]** **[Remedy]**

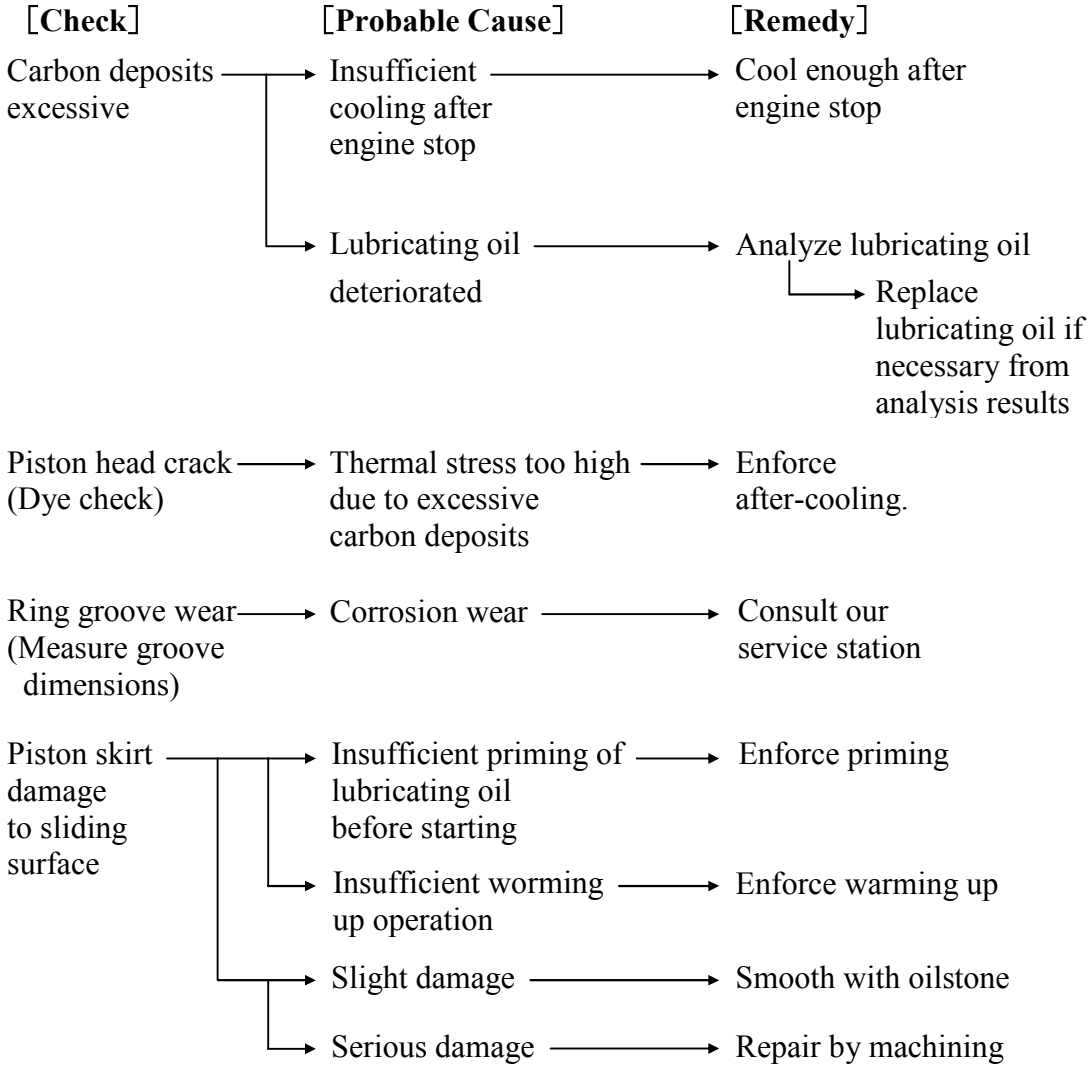
Excessive clearance

- Ring worn → Replace
- Ring groove worn
  - Work groove over size
  - Use over sized rings

NOTE : When you need over-sized rings, please inform us detail of it, beforehand.

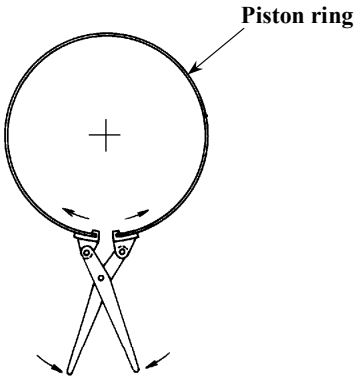
- Check that the compression rings (No.1 ring is made of special coating) have normal chrome plating on their outer surfaces, and no traces of blowby.
- Check that the oil rings are free of abnormal (uneven) wear, and have no damage to the lip at all.

(c3)Piston check

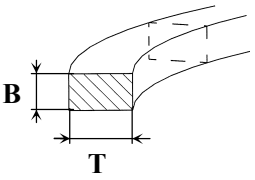


(d) Piston ring removal

Use the piston ring removing/fitting tool when removing piston rings.



Piston ring removing/fitting tool



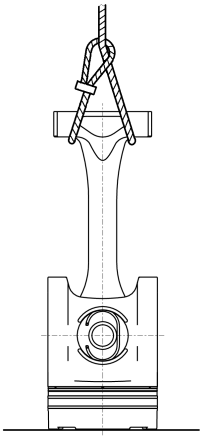
Ring	Original size	
	B [mm]	C [mm]
Top ring	6 $^{-0.01}_{-0.03}$	10.4 ±0.15
Second ring	6 $^{-0.01}_{-0.03}$	10.4 ±0.15
Oil ring	6 $^{-0.013}_{-0.028}$	5.5 ±0.15

(d1) Measure piston rings and oil rings for wear

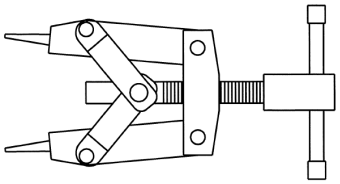
→ Replace rings seriously or unevenly worn

(e) Piston and connecting rod disassembly procedure

- Lift the piston and connecting rod assembly upside down, place it on a wooden board, and keep the connecting rod lifted so it will not fall.
- Remove the piston pin snap ring of one side with snap ring pliers.
- Pull up the connecting rod slightly and extract the piston pin



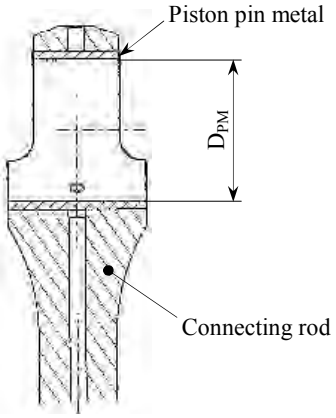
Piston and Connecting Rod Assembly Lifting and Placement



Plier for removing snap ring

(f) Piston pin bearing check

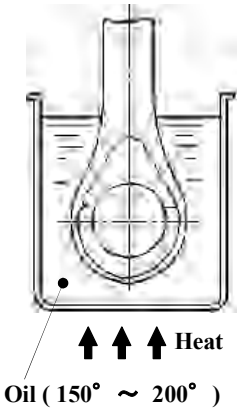
- Visually check the inner surfaces of the piston pin bearings.
  -Replace piston pin bearings that have serious scratches on their inner surfaces.
- Make a dye check on the inner surface.
  -Replace piston pin bearings that have cracked surfaces.
- Measure the inside diameter.



Measuring points		Measured valves	Permissible value
D_{PM1}	X direct.		Φ130.21 mm or less
	Y direct		
D_{PM2}	X direct		
	Y direct		

Piston Pin Bearing Inside Diameter Measuring Piston Pin Bearing Replacement Procedure

- In the shop, use a hydraulic jack to push out piston pin bearings.
- Measure the inside diameter of the connecting rod small end and the outside diameter of the bearing, and verify that shrink fit allowance is within the standard range of 0. 075 to 0. 12 mm. Heat the small end of the connecting rod in heated oil of 150°C to 200°C for 20 to 30 minutes. Don't use the fuel oil for heating.
- Completely wipe the oil off the contact surfaces of the connecting rod and bearing, and fit the bearing into the connecting rod. Heat the connecting rod until the bearing can be easily fitted into place.



NOTES : (1) The piston pin bearings have an overlay of lead and tin, but whether they should be replaced is not determined by the extent of wear to the overlay.
(2) Never use a file or sandpaper for smoothing roughened bearing surfaces. Simply use a scraper to remove projections.
(3) Determine whether piston pin bearings require replacement by measuring bearing wear. Clearances between piston pins and bearings may be used as reference data for repairs.
(4) Don't use the fuel oil for heating connecting rod.

(g) Connecting rod check

- Visually check the trunks of the connecting rods, or make a dye check on them, to verify that they are free of cracks and scratches.
- Check for condition of the mating surface of the connecting rod big-end and ,if occurrence of fretting etc. is observed ,make repairs with oil-stone.

⚠ CAUTION

If damage are found as below, consult our service station for repair methods because it may cause serious accident.

(1) Crack or scratches on the trunks of the connecting rods.

(2) Crack or fretting at serration parts.

(3) Crank pin stud screw hole is damaged.

(h) Crank pin stud check

- Check the threaded parts and seats of the crank pin studs for scratches. Replace if damaged.
- Check the shanks of the crank pin studs for rust and corrosion, and replace rusty studs.

NOTES : (1) The crank pin studs are the most important parts, which are exposed to the severest conditions. Thus, it is necessary to replace them periodically even if they appear normal.

Standard replace period 24,000 hours

(2) If an abnormal force is suspected to have been applied to the crank pin studs during engine operation (due to overspeed, for example), replace them regardless of their appearance.

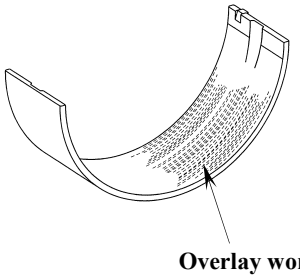
(3) If crank pin stud seats are corrected, or if crank pin studs are replaced, tighten the bolts in according to Paragraph **5.2** Tightening Specification of Main Parts and punch countermarks.

(i) Crank pin bearing check

[check] **[Probable Cause]** **[Remedy]**

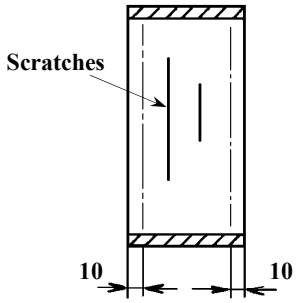
- Surface peeled or cracked → Lubrication faulty → Replace bearings
  - Lubrication faulty → Check lubricating oil system
  - Surface peeled or cracked → Lubricating oil deteriorated → Analyze lubricating oil

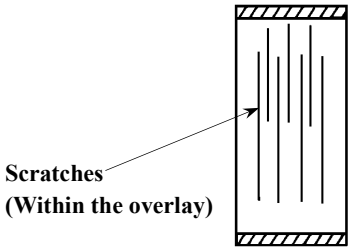
- Overlay worn → Worn more than 30% → Replace
  - Overlay worn → If overlay wear is less than 30%, bearing is still usable



(If overlay wear is expected more than 30% by next maintenance. Replace)

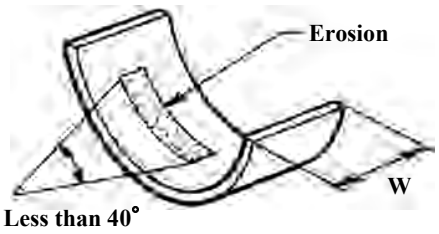
- Check inner surfaces for scratches due to foreign matter.
  Used bearings have some scratches due to foreign matter, but serious scratches may cause problems. Observe the following criteria.
  - Scratches made by foreign matter within 10 mm from the bearing edges are permissible.
  - Bearings with scratches made by foreign matter more than 10 mm inward from the bearing edges may be used again in the following cases.
  - Scratches reaching the kelmet layer and shiny, but not continuous all around, and more than 2 mm apart from each other are permissible.
  - Scratches within the overlay (not reaching the kelmet layer) are permissible even if they are continuous all around and are close to one another.





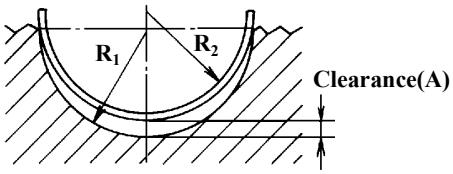
⚠ CAUTION
Do not repair bearing surface because will cause bearing seizure.

- Check for foreign matter which stuck into the bearing surface.
  If foreign matter is striking into the bearing surface and makes a bulge around it and has gloss, remove the foreign matter, and carefully finish the part around it with a scraper.
  If the sticking of foreign matter occupies as much as 2/3 of the bearing surface, replace the bearing
- Check for erosion.
  The bearings are subject to erosion due to lubricating oil pressure distribution, but these hardly cause problems. Whether eroded bearings are usable can be determined by the following standard.
  - Bearings eroded less than 1/5 of their width at the center and less than 40° of their inner circumference can still be used.



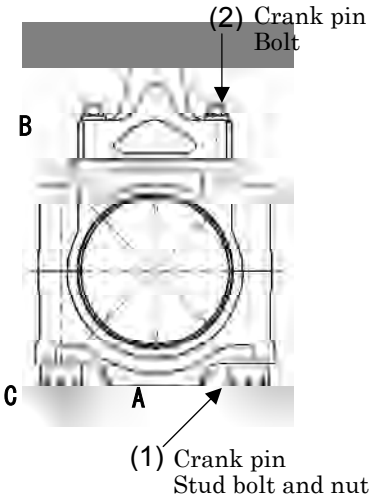
[Check]	[Remedy]
• Lack of tension	→ Replace.

Place a bearing in the bearing housing in a natural state, and if the clearance (A) between its outer surface and the bearing housing is less than 0.5 mm, replace the bearing.



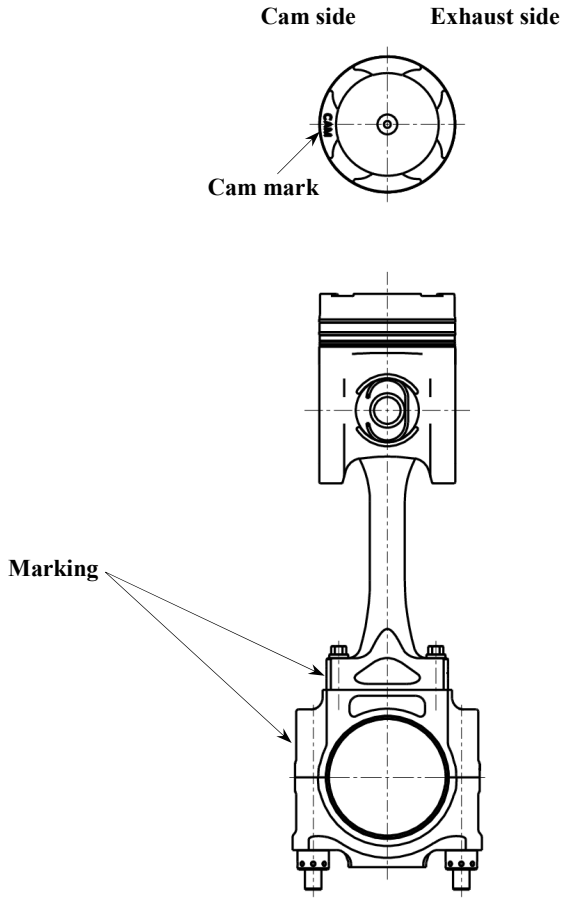
(j) Lubricating oil hole check
Clean the oil hole with light oil, and air blow.

(k) Measuring big end inner diameter
・Measure it following procedure.
(1). Tight stud bolts and nut of crank pin not to fit a crank pin bearing.
(2). Tight crank pin bolts.
(Refer to Chapter 7.5.2 (n) to see tightening order)
(3). Measure inner diameter of big end as 3 points shown in the right figure(φA, φB, φC).



(l) Piston and connecting rod assembly procedure

- Place a piston upside down.
- Make sure air to flow through the oil way to clean up the inside and, at the same time, make sure that the oil way is free from abnormality.
- Fit a piston pin snap ring into place on one side only.
- Apply lubricating oil to the piston pin and piston pin bearing , insert piston pin into piston.
- Place the together snap ring into place.



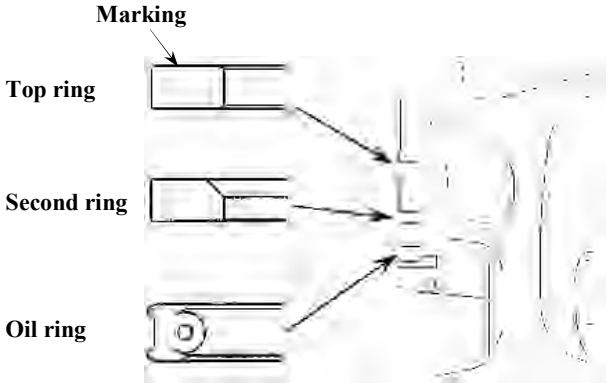
Assembly marks on piston and connecting rod

NOTES : (1) Check that piston and connecting rod are same cylinder number and it marking (cam side) before assembling them. And check that assembling directions are correct and agreement.

(2) Check that snap ring has properly tension. Replace, if not.

(m)Piston ring installation procedure

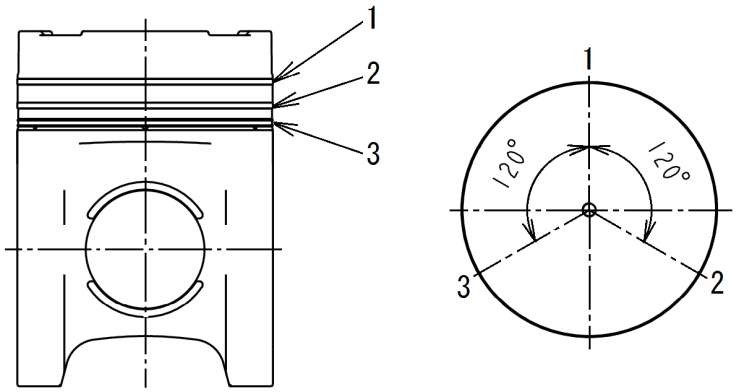
- Fit new piston rings into the ring grooves with the piston ring removing/ fitting tool.
  -Refer to **7.5.2(d)**
- At first, insert the oil ring with the piston groove.
- Be careful of the ring directions, and make sure that the various rings are installed in the correct position in the correct way. (Piston ring and oil ring's marking is combustion side)



Kinds of piston ring and their installation positions

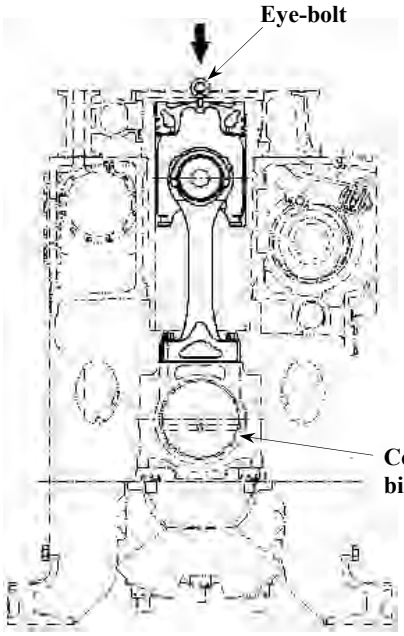
(n) Piston and connecting rod installation procedure

- Thoroughly clean the crank pin bearings with light oil.
  As in cleaning the crank pin bearings, do not use coarse rags, but wipe them carefully with a soft, clean cloth.
- After wiping the backs of the bearings and the inner surfaces of the connecting rods and caps dry with a clean cloth to remove oil, fit the bearings into the connecting rods and caps.
- Apply fresh lubricating oil to the inner surfaces of the bearings, using the palm of your hand.
- Make sure that the ring end gaps of adjacent rings are diametrically opposite each other.

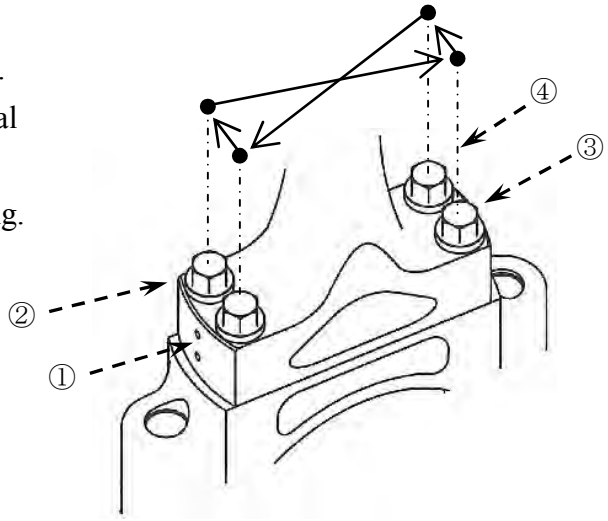


Piston Ring End Gap Positions

- Set a eye-bolt.
- For the subsequent steps, assembly procedure is carry out in the reverse to disassembly procedure.



- Tighten the crank pin bolts as described below until the counter-marks are aligned. Tighten the four bolts uniformly in diagonal order in three steps - primary tightening, intermediate tightening, and final tightening.



Tightening order: ①→②→③→④

- When replacing crank pin bolts, tighten them in the above manner in three steps - primary tightening, intermediate tightening, and final tightening - by referring to the bolt elongation standard described in Paragraph **5.2** Tightening Specification of Main Parts.

⚠ CAUTION

(1) The crank pin bolts are particularly important parts which must handled with great care, and tightened with the correct tightning force.

Faulty, tightning, and, in particular, insufficient tightning is very dangerous as it can lead to a serious accident.

(2) Whenever engine overspeed trouble or a serious piston scuffing has occurred, be sure to replace the crank pin bolts even if they appear normal. This is essential for safety.

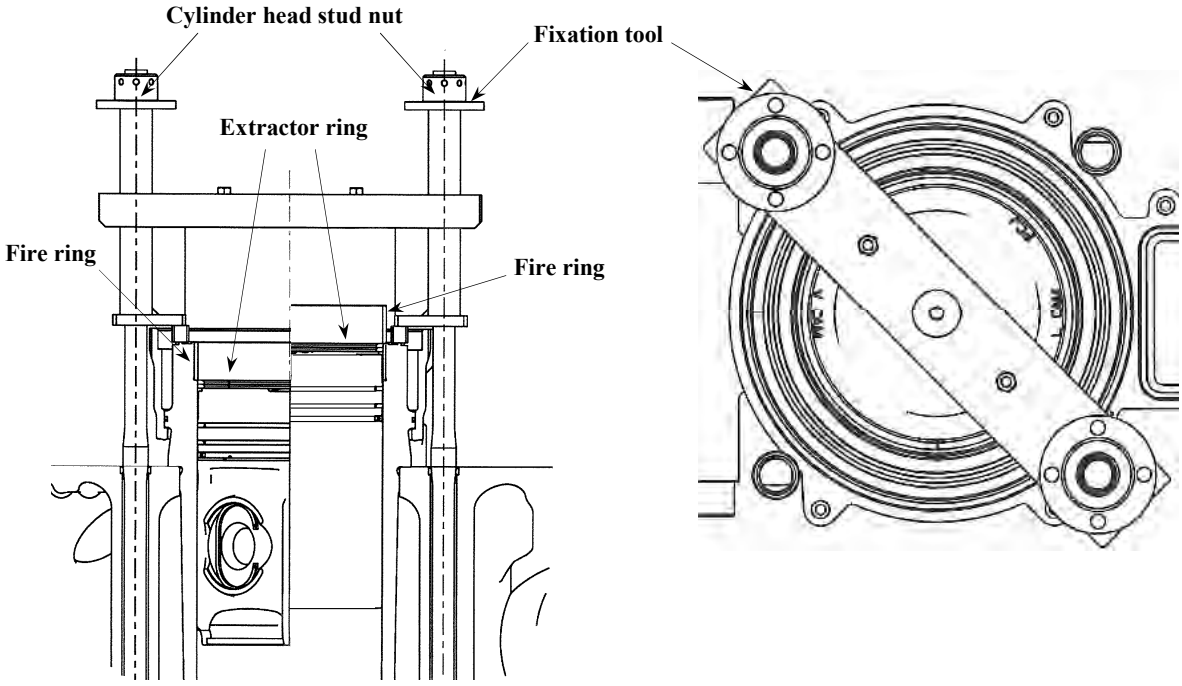
(3) When renewing the crank pin stud & nut. Clamp them temporarily under the regular hydraulic presser outside the engine. After stamping match, assemble them into the engine and be sure to check that match marks will match with each other.

7.5.3 Cylinder liner check

(1) Fire ring check

(a) Fire ring removal procedure.

- Apply penetrating oil, ex. CRC, between cylinder liner and outer surface of fire ring about 30 minutes.
- Set the fixation tool using the cylinder head stud nuts.
- Turn crank shaft and go down piston.
- Set the extractor ring between piston and fire-ring.
- Remove the pin and the fire ring after raise the piston position by turning.



Before turning **After turning**

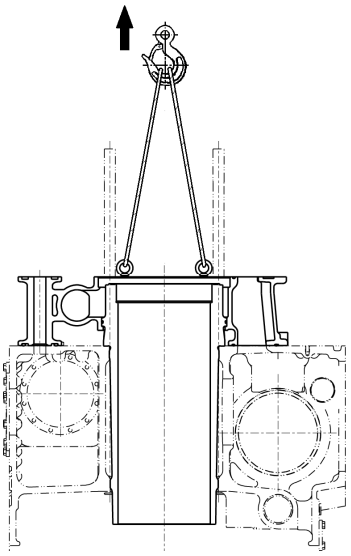
(b) Fire ring check

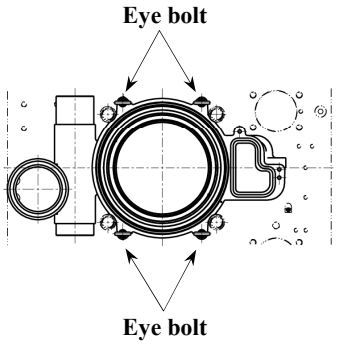
[Check]		[Remedy]
(b1) Damage to sliding	Slight	Smooth with oilstone
	Serious	Replace gears
(b2) Make a dye check		Replace if cracked
(b3) Measure the fire ring diameter		Replace if over-limit
(b4) Measure clearance between liner and fire ring		Replace if over-limit

(2) Cylinder liner check

(a) Cylinder liner removal procedure

- Remove piston and connecting rod.
- Fix the eye bolt at the top of liner ri (M12 4 place)
- Pull out the liner ring with cylinder liner.





(b) Liner check (without removing the cylinder liner from the engine)

(b1) Inner surface condition

[Check]	[Probable Cause]	[Remedy]
• Scuffing • Scratching	Cylinders overcooled	Carefully regulate cooling water temperature - Refer to Paragraph **5.3** Temperature Settings
	Sudden increase load	Gradually increase in load
	Piston cooling is not enough	Check cooling water jacket of piston head for carbon deposits, and cooling oil hole for blockage.
	Compression	Check compression rings for stickiness and breakage ring faulty
	Oil ring faulty	Check oil rings for breakage
	If scuffs are slight	Smooth with oilstone
	If scuffs are serious	Replace
• Combustion parts cracked	Over load	Replace

NOTE : Liners tend to be scuffed or scratched in a relatively early period (when the liners and pistons have not yet been enough run in.)
Old scratches may be permissible if the scratches are smoothed already.

(b2) Bore measuring

- Measure the bore, and compare the values with shop inspection records to confirm the amount of liner wear.
- Measure the amounts of liner wear in crankshaft directions and at right angles thereto to confirm whether or not the cylinder liners are evenly worn.

(b3) Make a dye check

- Cylinder liner upper part (inner and outer) check

[Check]	[Remedy]
Cracked	Replace

(c) Liner check (with removing the cylinder liner from the engine)

(c1) Outer surface corrosion

[Check]	[Probable Cause]	[Remedy]
• Outer surface corrosion	Primary cooling water pressure dropped	Adjust water pressure Refer to Paragraph **5.4** Pressure Settings
	Cylinder vibration excessive	Measure vibration
	Air mix into cooling water (Air venting incomplete)	Completely remove air from cooling water
	Primary cooling water quality unsuitable	Use inhibitor
		Spread plastic metal into corroded part
		If corroded more than 8mm deep, replace

NOTE : Corrosion of the outer surface of the liner is described as cavitation corrosion, it is caused by the explosive power generated by burning fuel, liner vibration by piston slapping, and cooling water pressure, and generally occurs in thrust directions. Thus, it is necessary to regulate the primary cooling water pressure carefully. The following steps are recommended if cavitation corrosion is found.

(1) Repair method

- Smooth the corroded part with a sander or grinder.
  Necessary to completely flatten the recess made by corrosion
- Remove rust from the corroded part with a wire brush.
- Remove oil from the corroded part with paint thinner or gasoline.
- Fill the corroded recess with a well-prepared repair material such as plastic metal

using a spatula in a rubbing manner.

(2) Repair material

Repair material recommended

BELZONA MOLECULAR

Ceramic S-metal

Supplier;

BELZONA MOLECULAR INCOP.,

222 Seven Street Garden City New York 11530

Tel: (516) 746-7030

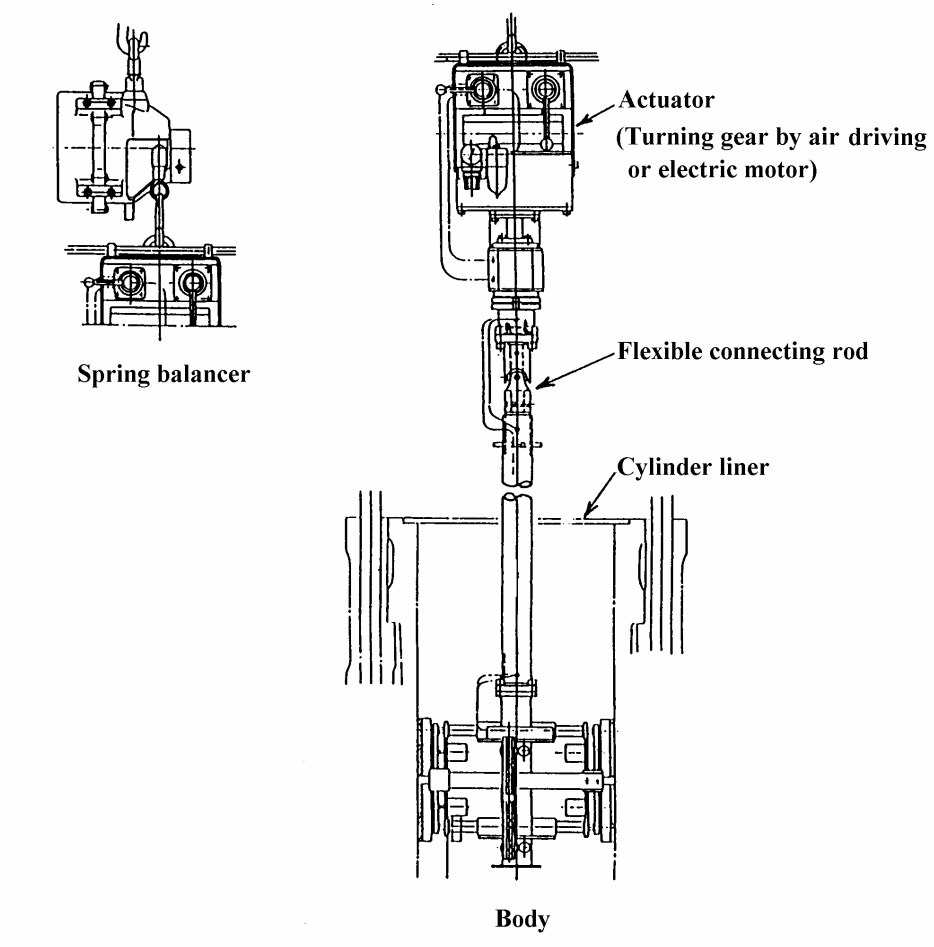
(d) Cylinder liner deglazing

If the inner surfaces of the cylinder liner are like a mirror, deglazing them to make fine oil recesses on the liner surfaces, which will ensure satisfactory lubrication and reduce liner wear.

(d1) By honing (Ra 1.6 μm): Cylinder liners must be sent to a service shop.

(d2) By grazing machine : Cylinder liner can be repaired on site.

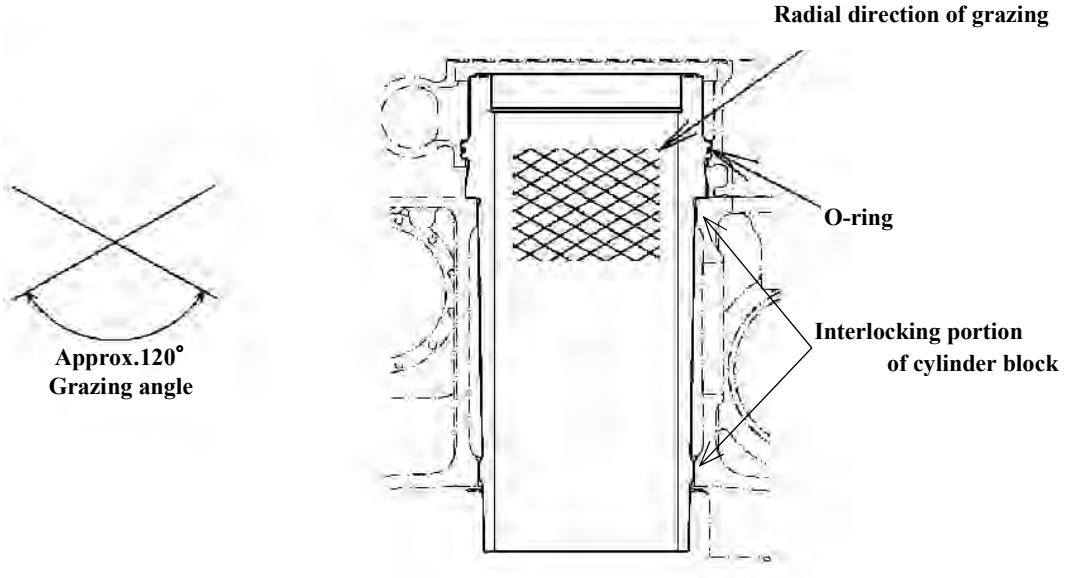
Grazing is without removing the cylinder liners from the engine. And cover the liner bottoms with a vinyl bag or the like so that grazing dust will not fall into the crankcase.



(d3) With sandpaper (No.40): Cylinder liners can be repaired on site.

Polish the cylinder liners with sandpaper (No.40) in a circumferential 120° direction, but never vertically, until traces of sandpaper are visible.

When doing this without removing the cylinder liners from the engine, cover the liner bottoms with a vinyl bag or the like so that sandpaper dust will not fall into the crankcase.



(e) Liner ring check

[Check]	[Remedy]
• Liner ring faulty	→ Repair or replace
• Check and clean rust in the water jacket.	
• Check and clean intake manifold	

(f) Cylinder liner assembly procedure

- Thoroughly clean the outer surface, and apply anti-corrosive paint to them.
- Set the cylinder liner to liner ring.
- Use the eye-bolt for lifting the liner ring with cylinder liner.

NOTE : The cylinder liners fall into place under their own weight or are pushed into place by lightly tightening the cylinder heads. If insertion is difficult, do not force them because it indicates that something must be wrong. Check for the cause of the trouble.

- O-rings not fitted properly
- Check the clearances between the cylinder liners and crank case.

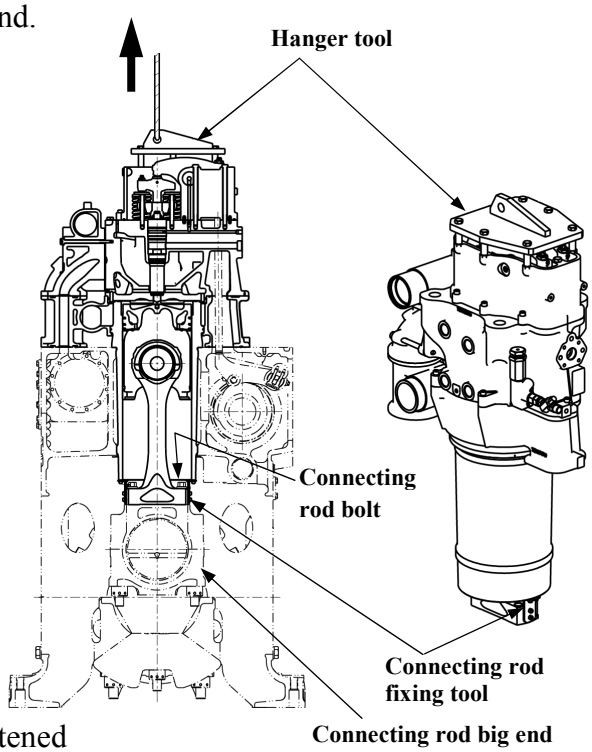
7.5.4 Cylinder unit removal, assembly procedure

(Component part: Cylinder head assembly, Rocker arm assembly, Piston assembly, Cylinder liner assembly, Connecting rod assembly, Intake and Exhaust valve assembly.)

(a) Cylinder unit disassembly procedure

(a1) Remove following parts from them beforehand.

- Cylinder head cover
- Fuel oil pipe cover
- Fuel injection pipe
- Fuel drain pipe
- Lubricating oil pipe
- Cooling water pipe
  (connection pipe, coupling)



(a2) Disassemble and fix the connecting rod

- Set the socket and a ratchet handle from the crankcase door.
- Loosen the connecting rod bolts.
  At this time, the bolts are temporarily tightened in the extent that can be turned by the hand.
- Turn and adjust the piston to the top dead center**.**
- Remove the crankpin bolts.
- Fix the cylinder liner on the connecting rod by the bolts with the connecting rod fixing tool.

(a3) Loosen the cylinder head stud nuts by hydraulic jack (tool).

- Refer to **7.5.1**(2) Cylinder head overhaul.

(a4) Lift the cylinder head unit

- Set the bracket into rocker arm support, and then pull the cylinder unit guradually.

It is dangerous to rotate the big end cap when crank pin bolts are removed.
Be careful to pull out connecting rod.

(b) Cylinder head unit reassembly procedure

Assembly procedure is carried out in the reverse order to disassembly procedure.

- Refer to **7.5.1**(2)(d) Cylinder head assembly procedure.

7.5.5 Fuel injection pump check

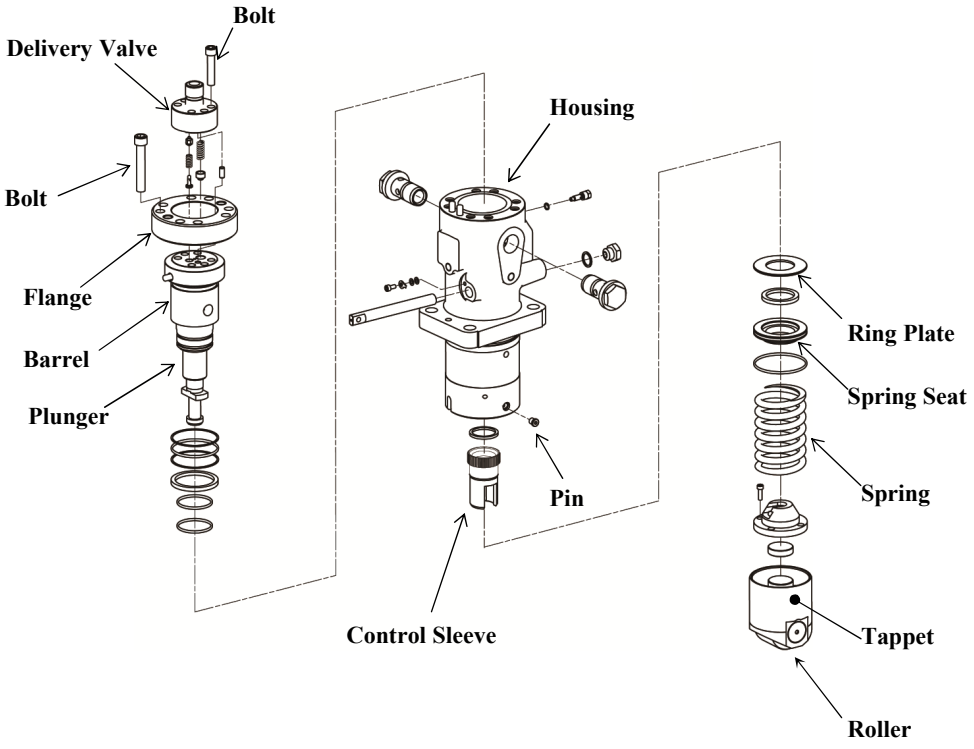
(a) Assume pump performance drop from engine performance.

[Check]	[Probable Cause]
• Maximum cylinder pressure dropped	Plunger wear increased
Rack scale advanced	
Pump oil leakage increased	

NOTE : The lives of the fuel injection pump plungers and barrels depend largely on the properties of the fuel oil. It is advised to send the pumps to a qualified shop for judging whether the plungers and barrels are good or not.

(b) Pump disassembly procedure

- Remove the delivery valve holder at the top, and take out the delivery valve.
- Remove the flange and the barrel.
- Remove the dowel pin first and then the tappet with the plunger.
- Remove the spring and the control sleeve.
- Push out the ring plate and spring seat from the housing.



NOTE : The fuel injection pump parts are precision-finished. Immerse disassembled parts in fresh light oil to keep them free of rust and dust.

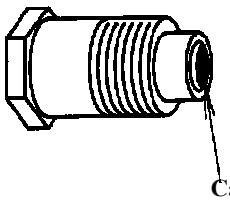
(c) Disassembly check

(c1) Plungers and barrels

[Check]	[Probable Cause]	[Remedy]
• Sliding part worn	Fuel oil unsuitable (FCC oil)	Analyze fuel oil
	Not cleaned properly	Cleaning of fuel oil tank and discharge drains
	Clean filter carefully	
		Replace filter element if necessary
• Plunger top edge broken		Replace
• Cavitation		Replace

NOTE : (1) Be sure to replace plunger and barrel as a pair.
(2) If performance has dropped without any specific trouble, replace the plungers and barrels for all the cylinders at the same time. This is necessary to prevent uneven performance (uneven rack scale positions).
(3) When changing the plunger and barrel for a specific cylinder only, adjust the rack scale by refer to **6.1.1(1)(c)** to prevent uneven loading.

(c2) Deflector inner surface cavitation eroded ⟶ Replace

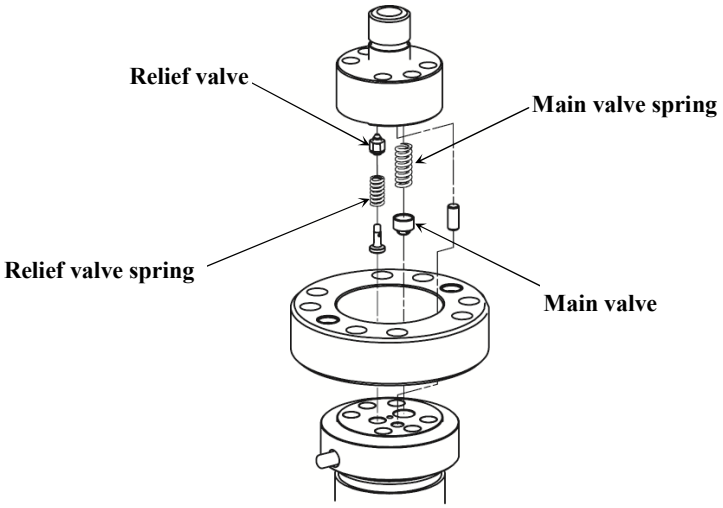


NOTE : The deflector is provided for protecting the pump body from erosion due to the return oil (high-pressure rushing oil) at the end of fuel injection. Replace it periodically because its tip becomes eroded with use.

(c3) Delivery valve check

- Disassemble the main valve and relief valve.
- Check the above valve seats and springs.

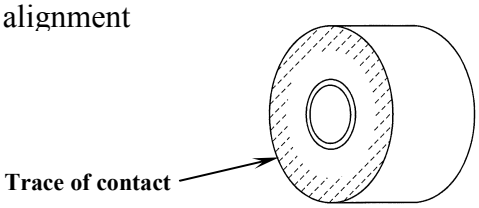
[Check]		[Remedy]
Spring and valve seat faulty	→	Replace
Irreparable body	→	Replace as assembly



Delivery valve (Constant pressure type)

(c4) Tappet roller Check

[Check]	[Probable Cause]		[Remedy]
• Damage to surface and corners			
Cracked or peeled	Slight	→	Smooth with oilstone
Wear	Serious	→	Replace
• Side contact →	Tappet roller and camshaft out of alignment	→	Check roller and cam contact, and align them



(c5) Roller bushing

• Damage to sliding surface →	Slight	→	Smooth with sandpaper
	Serious	→	Replace

(c6) Lubricating oil hole cleaning

- Clean that the tappet oil hole with light oil.

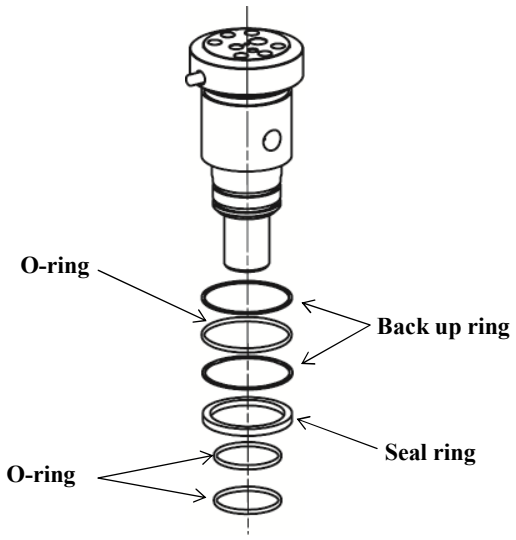
(d) Fuel injection pump assembly procedure

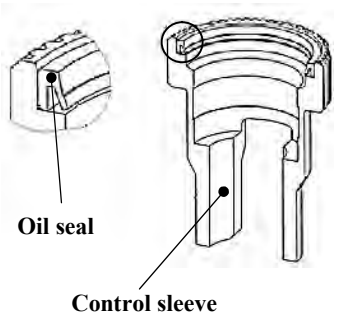
(d1) Clean the parts with fresh light oil. It is afraid to rust if assemble to leave the parts cleaning with light oil.

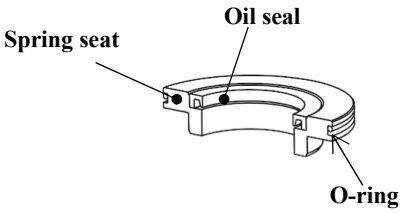
(d2) Apply grease to the parts, and carefully assemble them same as the figure to keep them face of foreign matter.

(d3) Replace the O-rings, back up rings, and oil seal.

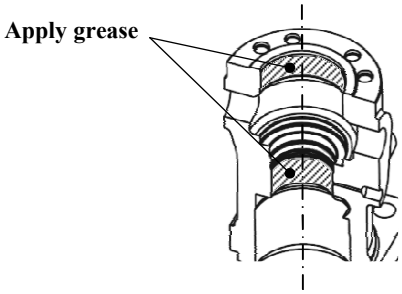
Apply grease to the O-ring, seal ring and set them on the barrel.

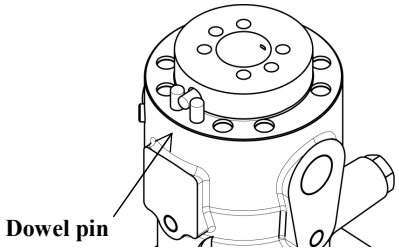




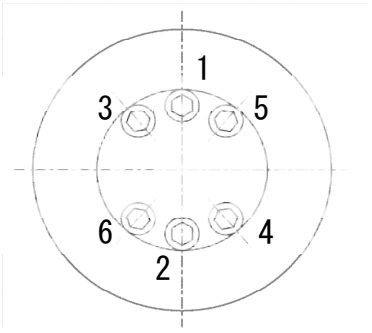


(d4) Apply grease to inside of the housing, install the barrel and set the dowel pin.





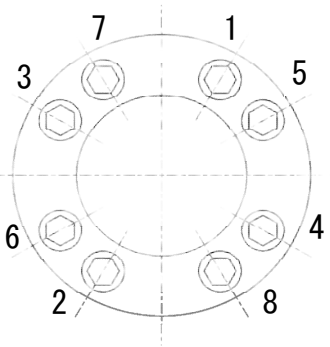
(d5) Tighten the bolts of delivery valve and flange.



a. Delivery valve

Tightening torque of three step.

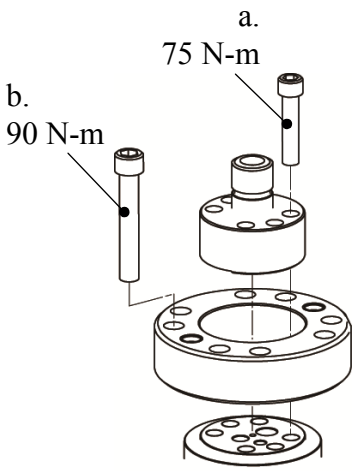
1) 25 N-m
2) 50 N-m
3) 75 N-m



b. Flange

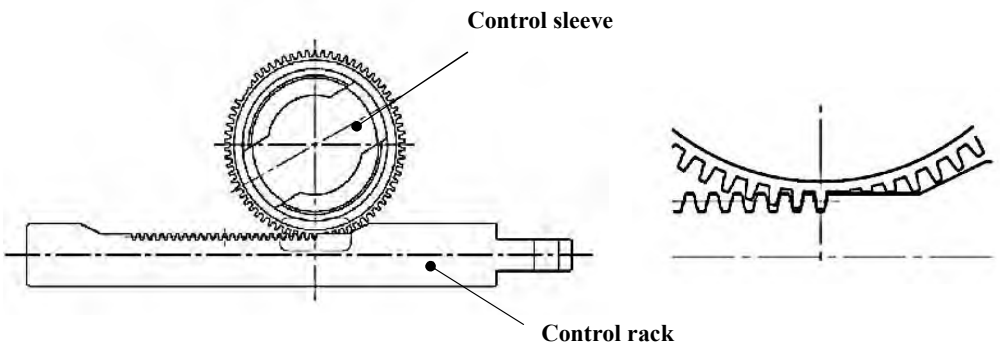
Tightening torque.

1) 90 N-m



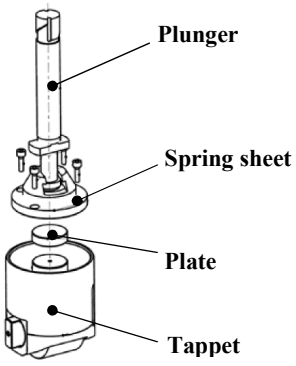
(d6) Reassemble rack and control sleeve by following method.

-Engage first tooth of rack and control sleeve.



(d7) Set the plate on the tappet and hang the spring seat on the plunger, install the plunger with spring seat into the tappet barrel so that the vane of the plunger engages the slots in the control sleeve.

(d8) Install the plunger into the barrel.



NOTE : (1) Be careful to avoid slantingly install.
(2) Be sure not to damage plunger.

7.5.6 Fuel injection union and joint check

(a) Fuel injection unions check

Visually check

[Check]			[Remedy]
Seat surface contact incomplete	→	Slightly	→ Lapping
		Serious	→ Replace

(b) Bolt check

- Thread scratch cracked → Replace

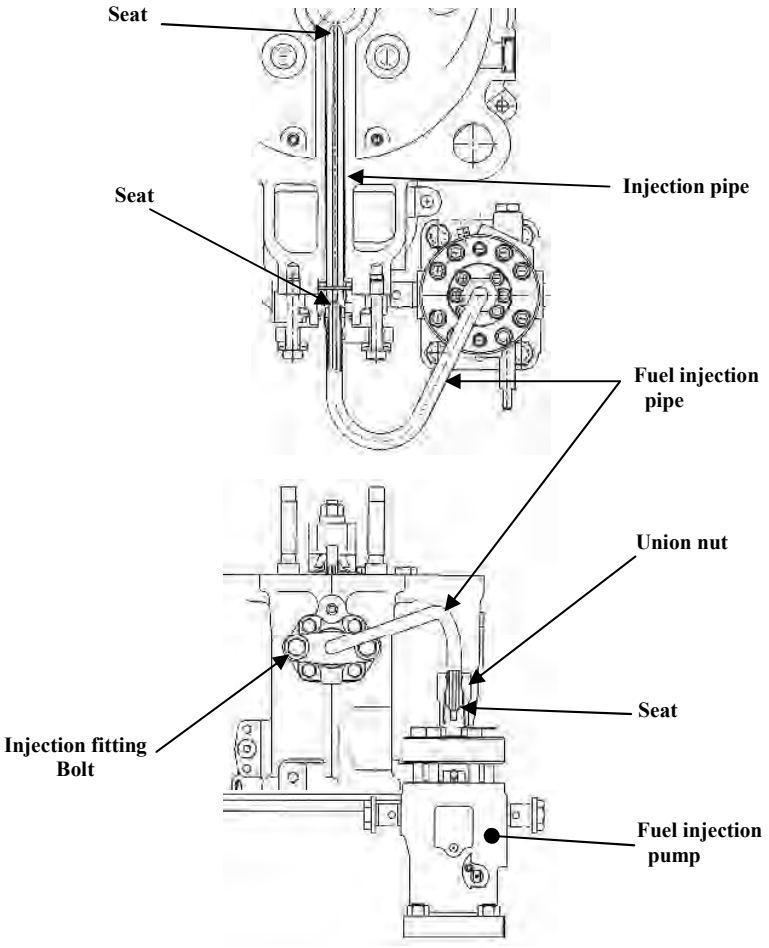
(c) Fuel injection union and joint assembly procedure

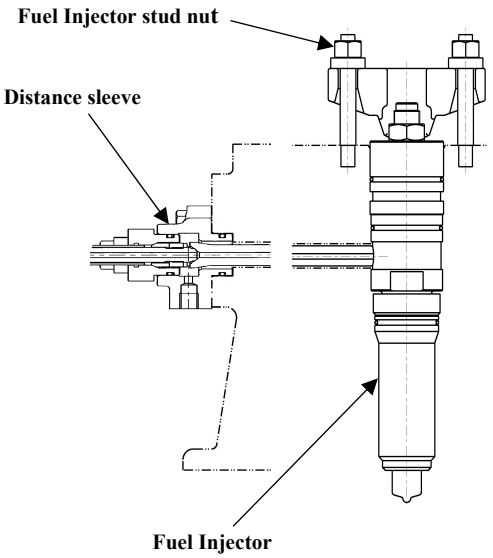
- Tightening procedure , as follows :
  - (1) Injection fitting Bolt preliminary tighten.
  - (2) Fuel Injector stud nut tightening torque : 100 N-m. Apply lubricating oil
  - (3) Injection Joint and Union nuts tightening.

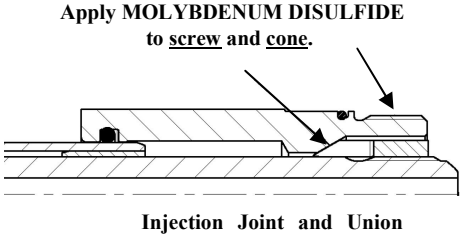
    Apply MOLYBDENUM DISULFIDE to screw and cone.

    Injection fitting Bolt tightening torque : 60 N-m.

    Union nuts Tightening torque : 75 N-m





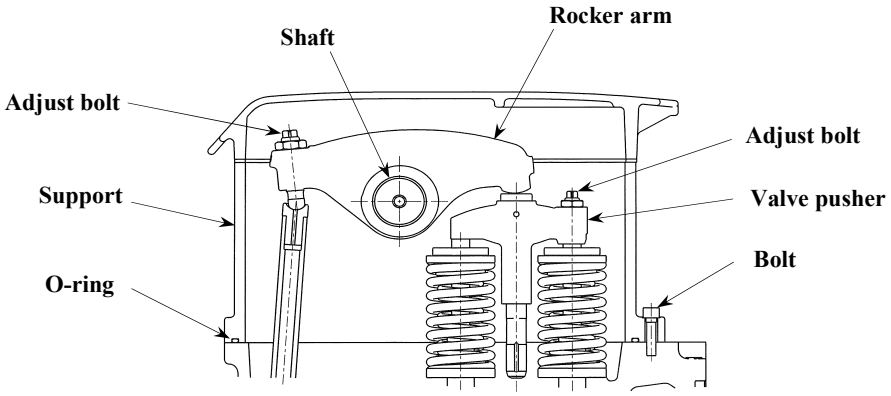


Injection Joint and Union

7.5.7 Intake and exhaust valve rocker gear check

(a) Intake and exhaust valve tappet clearance check

[Check]	[Probable Cause]	[Remedy]
• Excessively large tappet clearance	Push rod top and bottom pieces worn	Refer to each maintenance procedure
	Roller guide push rod pieces worn	
	Adjust bolt tip and each pieces worn	
	Cam and cam roller worn	
• Excessively small tappet clearance	Valve and valve seat worn	Refer to intake and exhaust valve maintenance



(b) Rocker arm disassembly procedure

- Loosen the support upper bolt, and remove the rocker arm, then pull out valve pushers.
- Remove the snap ring and collar, and pull out the rocker arm.

(c) Rocker arm gears check

[Check]	[Probable Cause]	[Remedy]
(c1) Rocker arm shaft worn	Lubricating faulty	Repair by grinding
		Replace rocker arm bushing (with an underside bushing)
	Lubricating oil pump faulty	Check pump

(c2) Rocker arm bushing

- Worn → Replace
- Inner surface roughened → Smooth with sandpaper or replace

(c3) Adjust bolt tip and each piece worn → Replace

(c4) Rocker arm dye check

- Cracked → Slight → Repair by grinder
- Cracked → Serious → Replace

(c5) Lubricating oil hole cleaning

Clean that the support, rocker arm, and shaft lubricating oil hole with light oil.

(c6) Measure the clearance between shaft and bushing

— Refer to Paragraph **5.1** Parts adjustment standard.

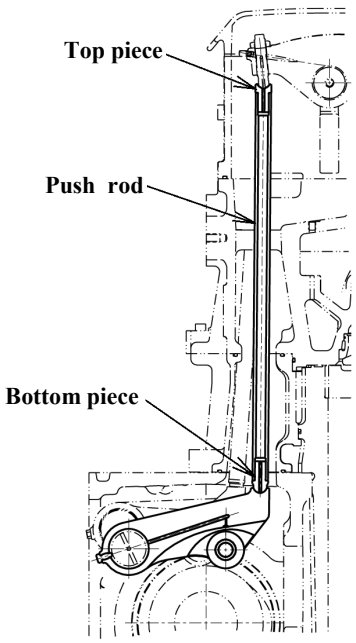
(d) Rocker arm gears reassembling

Reassembling is carried out in the reverse order to disassembly procedure.

- When set rocker arm gears into cylinder head, bring the piston for the cylinder to be adjusted to the combustion top dead center, tighten the bolt of support.
  — Refer to Paragraph **5.2** Tightening Specification of Main Parts
- Adjust the tappet clearance to 0.5mm
  — Refer to Paragraph **6.1.1(1)(g2)**

7.5.8 Intake and exhaust push rod check

[Check]	[Remedy]
• Push rod top and bottom pieces worn	→ Replace
• Push rod bend	→ Repair or replace



7.5.9 Cams and valve gear check

(a) Disassembly

(a1) Remove the valve gear from the cylinder block.

(a2) Remove the snap ring from roller pin.

(a3) Remove the roller.

(b) Check

[Check] **[Remedy]**

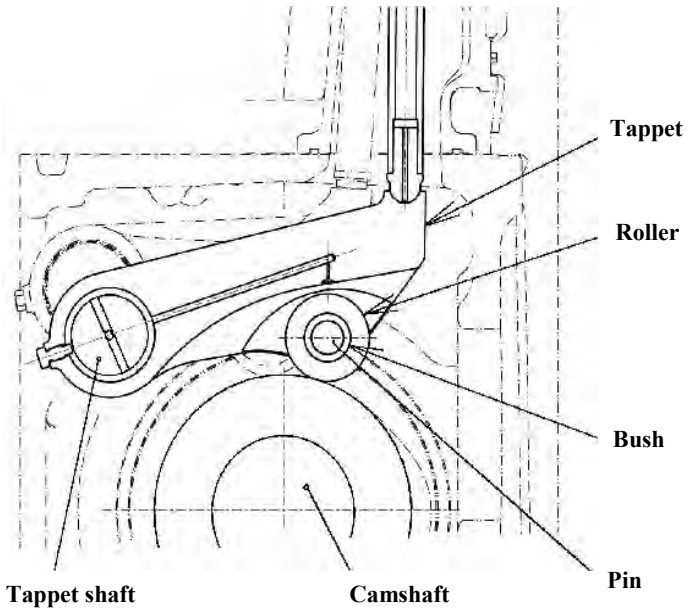
- Damage to cam surface and cam rollers
  - Cracked or peeled → Slight → Smooth with oilstone
  - Worn → Slight → Smooth with oilstone
  - Worn → Serious → Replace
- Cam deviation → Serious → Replace
- Roller bush
- Damage to sliding surface → Slight → Smooth with sandpaper
- Damage to sliding surface → Serious → Replace

(c) Make a Dye check

Intake and exhaust roller check same procedure of fuel injection pump.

(d) Reassembly procedure

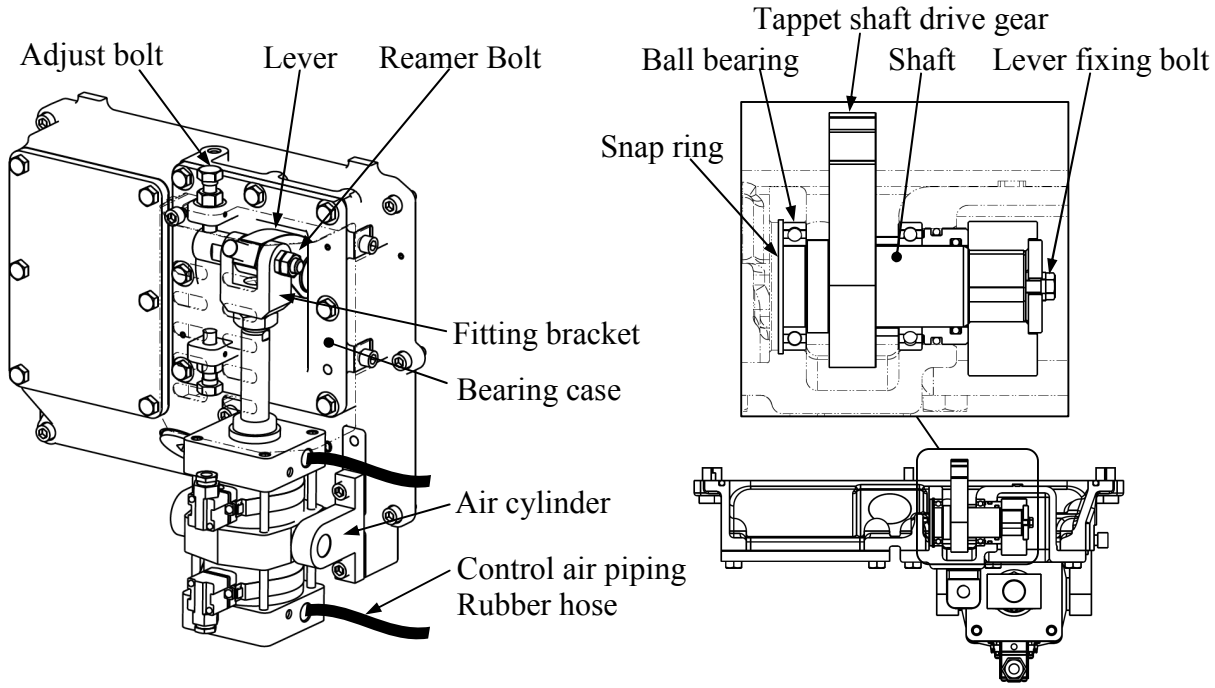
Assembly procedure is carried out in the reverse order to disassembly procedure.



7.5.10 VIVT Tappet shaft drive unit check

(a)Disassembly procedure

- Remove the reamer bolt connecting the fitting bracket and the lever.
- Remove the air cylinder and bearing case.
- Remove the lever fixing bolt and lever.
- Remove the snap ring fixing the drive shaft bearing, and remove the bearing.



NOTE : (1) Release the control air when disassembling the tappet shaft drive.
(2) Do not loosen the adjustment bolt.

(b)Check

［ Check ］	[Probable Cause]	［ Remedy ］
• Does not work smoothly	Insufficient lubrication of the moving part	Grease-up of the moving part
• Linkage excessive loose	Wear of fitting bracket, reamer bolt	Replace
	Tappet drive gear worn	Replace
	Ball bearing worn	Replace
• Control air piping rubber hose crack	Aging deterioration	Replace
• Air cylinder movement is not smooth	Insufficient lubrication	
• Air cylinder air leaks	Air seal worn	Replace

(c) Reassembly procedure

- Assembly procedure is carried out in the reverse order to disassembly procedure.

7.5.11 Gear wheel check

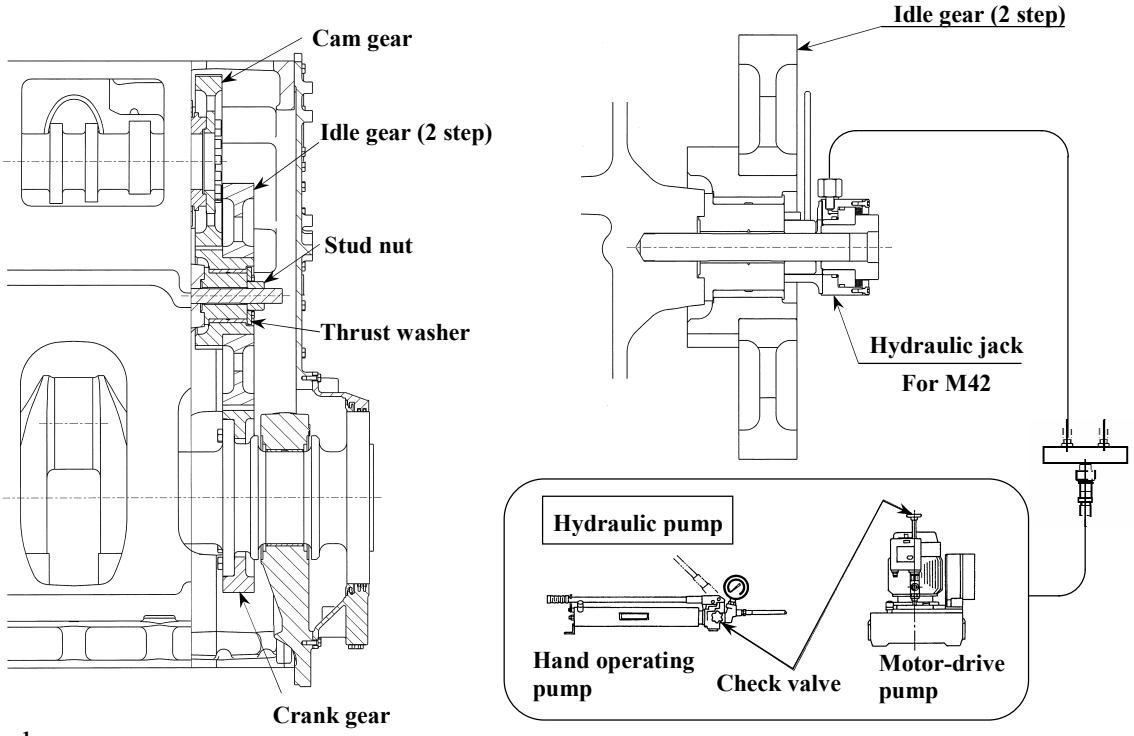
(1) Driving end side gear train

(a) Disassembly procedure

- Remove the turbo charger bracket (T/C driving end side spec) or gear case cover (T/C free end side spec.)
- Remove the thrust washer , and then loosen the stud nuts by hydraulic jack.

- Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Threads Size
Idle gear shaft	3mm	1 rotation	M42×3



(b) Check

(b1) Visually check each gear from the check window or disassembled.

［**Check**］ ［**Remedy**］

- Gear surface pitted → Slight → Smooth with oilstone
- Gear surface pitted → Serious → Replace gear
- Check gear backlash → Repair if necessary
  Refer to Paragraph **5.1** Clearance and Wear Limit

(b2) Bushing check

- Measuring inner diameter → Replace if excessive worn
- Measuring clearance → Replace if excessive clearance
  Refer to Paragraph **5.1** Clearance and Wear Limit

(c) Reassembly procedure

- Assembly procedure is carried out in the reverse order to disassembly procedure.

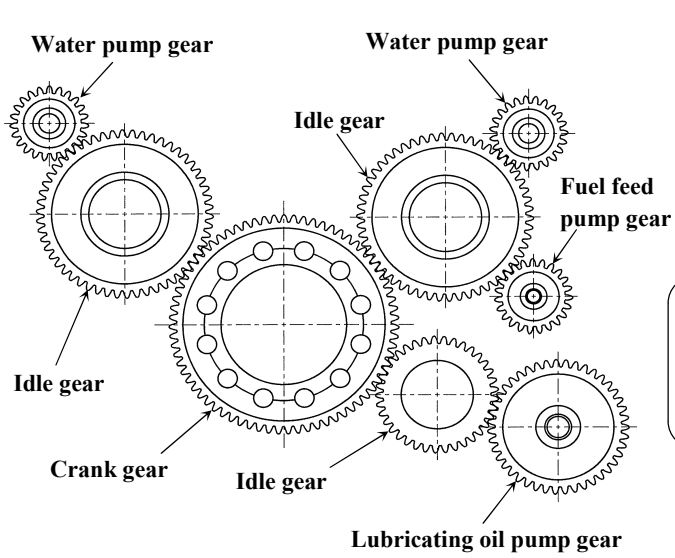
(2) Free end side gear train

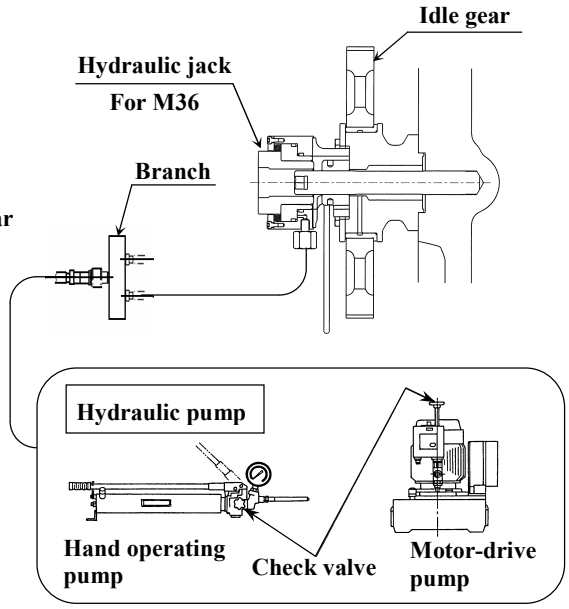
(a) Disassembly procedure

- Remove torsional damper
- Remove crank gear
- Loosen the stud nuts by hydraulic jack

- Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Threads Size
Idle gear shaft	2mm	1 rotation	M36×2





(b) Check

(b1) Visually check each gear from the check window or disassembled.

［**Check**］ ［**Remedy**］

- Gear surface pitted → Slight → Smooth with oilstone
  → Serious → Replace gear
- Check gear backlash → Repair if necessary
  Refer to Paragraph **5.1** Clearance and Wear Limit

(b2) Bushing check

- Excessive clearance → Replace bearing
- Inside surface peeled → Lubrication faulty → Replace bearing
  → Check lubricating oil system
  → Lubricating oil deteriorated → Analyze lubricating oil

(c) Reassembly procedure

- Assembly procedure is carried out in the reverse order to disassembly procedure.

7.5.12 Main bearing check

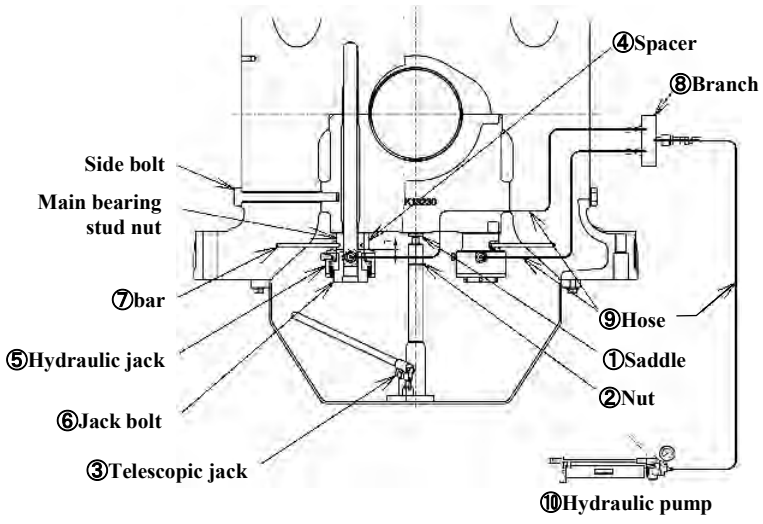
(a) Main bearing disassembly procedure

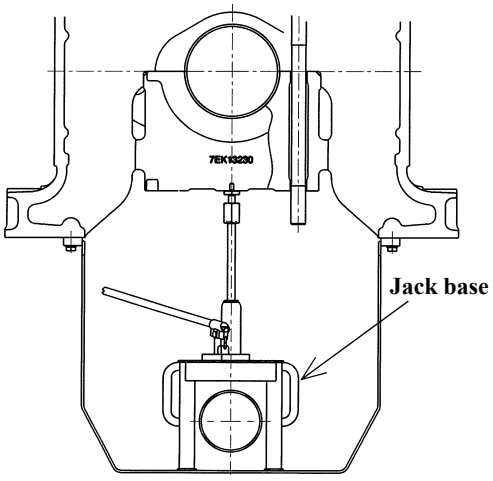
(a1) Loosening bearing stud nuts (Refer to following Fig.)

- Screw ① clamp and ② nut onto the main bearing cap bottom surface.
- Set the ③ telescopic jack, and lift up until upper limit.
- Adjust the ② nuts, and set it into the tip of telescopic jack.
- Set the ④⑤⑥ hydraulic jack to the two main bearing studs.
- Screw the ⑥ jack bolt by hand, and then screw it until the ④ spacer touches the main bearing cap. At this time, check parallel between the under surface of the ⑤ jack body and the seat of the main bearing cap.

  (The clearance between the main bearing stud nut and jack bolt becomes approx. 7mm.)

  After that, half turn of the jack bolt. (Because of s case of shrinking and locking the jack bolt when it is disassembled with the hydraulic jack)
- Connect the hydraulic jack and ⑧ distributor with the ⑨ high pressure hose.
- Connect the ⑧ distributor and the ⑩ hydraulic pump with the ⑨ high pressure hose.
- Increasing the hydraulic pressure slightly with the ⑩ hydraulic pump.
- Operate ⑩ hydraulic pump to rise hydraulic pressure to 180MPa, and then turn back the main bearing stud nut with ⑦ bar.
- If it is hard to turn, increase the hydraulic pressure up to 190MPa.





In case of wet sump oilpan

- Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Threads Size
Main bearing stud	3mm	1 rotation	M42×3

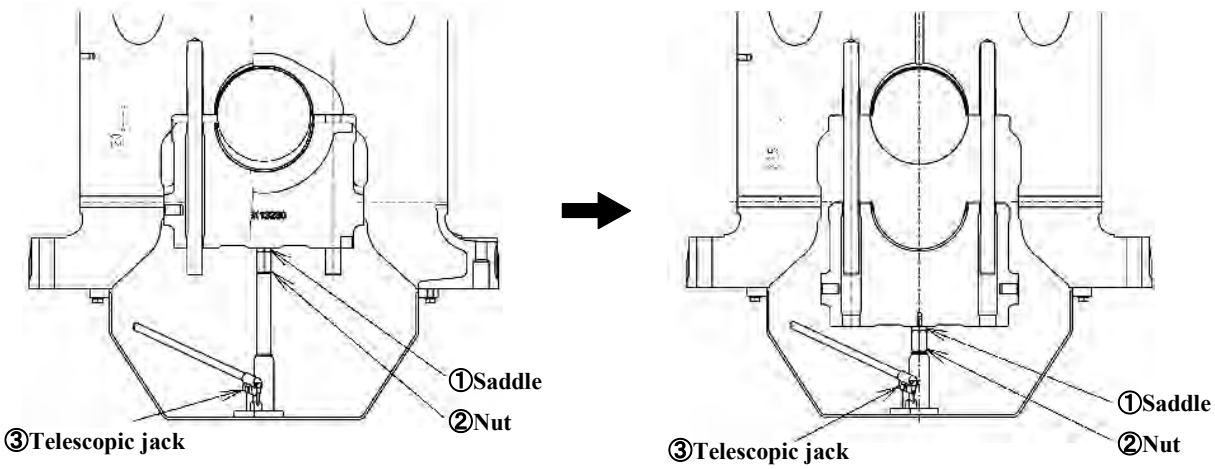
WARNING

When using the hydraulic tools, if high pressure oil ejected, there is a danger of injuring. If high pressure oil spray enter into the body through the skin, consult a physician immediately. Make sure carefully check the joint part of the hydraulic tools before increasing the hydraulic pressure.

NOTE : (1) If the hydraulic pressure is hard to rise it may be due to remaining air in the pump and hoses, then, disconnect the hoses at jack connection(couplers) to discharge the air.
(2) If it is hard to turn back the main bearing stud nut with the jack at the pressure 190MPa, something may be matter with the tools or fitting work.

(a2) Main bearing disassembly (Refer to following Fig.)

- Loosen and remove the side bolts.
- Remove the ⑨ high pressure hose from the hydraulic jack.
- Remove the ④⑤⑥ hydraulic jack from the main bearing stud nuts.
- Loosen and remove the main bearing stud nuts by hands.
- Screw the ② nut until touching the ① clamp. (Main bearing cap took down)
- Reduce hydraulic pressure of the ③ telescopic jack gradually until lower limit of the main bearing cap position.
- Remove the lower bearing shell.



(a3) The upper bearing shell disassembly procedure.

- Insert the ⑪ bearing pusher(with O-ring) into the crankshaft oil hole. (Refer to **7.5.11** Fig.1)
- Turn the crankshaft in the arrow direction, and remove the upper shell.

⚠ WARNING

Before turning the engine, check that there is nothing dangerous near it, and inform the people around the engine, that you are turning it.

⚠ CAUTION

(1) When turning the engine, open the all indicator cocks surely. There is a danger of injuring.
(2) Before turning the engine, open the all indicator cocks surely. If not, there is very dangerous because the crankshaft may be reverse.

NOTE : (1) When the main bearing cap does not go down by the gravity, you have to loosen the fixation bolts around bearing.
(2) When the upper shell is extracted by ⑪bearing pusher, special care should be taken for operation of the turning motor. And be careful turning direction, because the bearing has a location notches.

(b) Main bearing check

Check the middle bearing only, and judge from it whether the other main bearings need to be checked.

Check the main bearing in the same way as the crack pin bearing by referring to **7.5.2**(i).

(c) Main bearing assembly procedure (Refer to **7.5.11** Fig.2)

- Wash and clean the upper bearing shells and wipe them with dry waste cloth.
- Apply new lubricating oil on the bearing inner surface only.
- Place the upper bearing shell on the crankshaft journal so their location notches agree, and then, insert the shell into the housing as deep as possible by hand.

If the upper bearing shell cannot be inserted to the right position, follow to the next.

- Place ⑫ shell guide on the main bearing cap.
- Set ⑪ bearing pusher(with O-ring).
- Operate ③ telescopic jack until ⑫ guide touches the housing.
- Turn the crankshaft to the arrow direction to insert the upper bearing shell.

NOTE : When the upper bearing shell is extracted by ⑪ bearing pusher, special care should be taken for operation of the turning motor. And be careful turning direction, because the bearing has a location notches.

- Lower the ③ telescopic jack until the bottom, and set the lower bearing shell.
- Jack up ③ telescopic jack again until an upper limit.
- Adjust the ② nut until the main bearing cap touches the housing.
- Screw the nuts by hand.
- Tighten the Exhaust manifold side bolt with a half of normal torque.
  (Apply MOLYBDENUM DISULFIED)
- Tighten the main bearing stud nuts in the reverse procedure of disassembly.
- Tighten the Exhaust manifold side bolt.
- Tighten the Camshaft side bolt.

— Refer to Paragraph **5.2** Tightening Specification of Main Parts

Fig.1 Upper bearing shell removing procedure

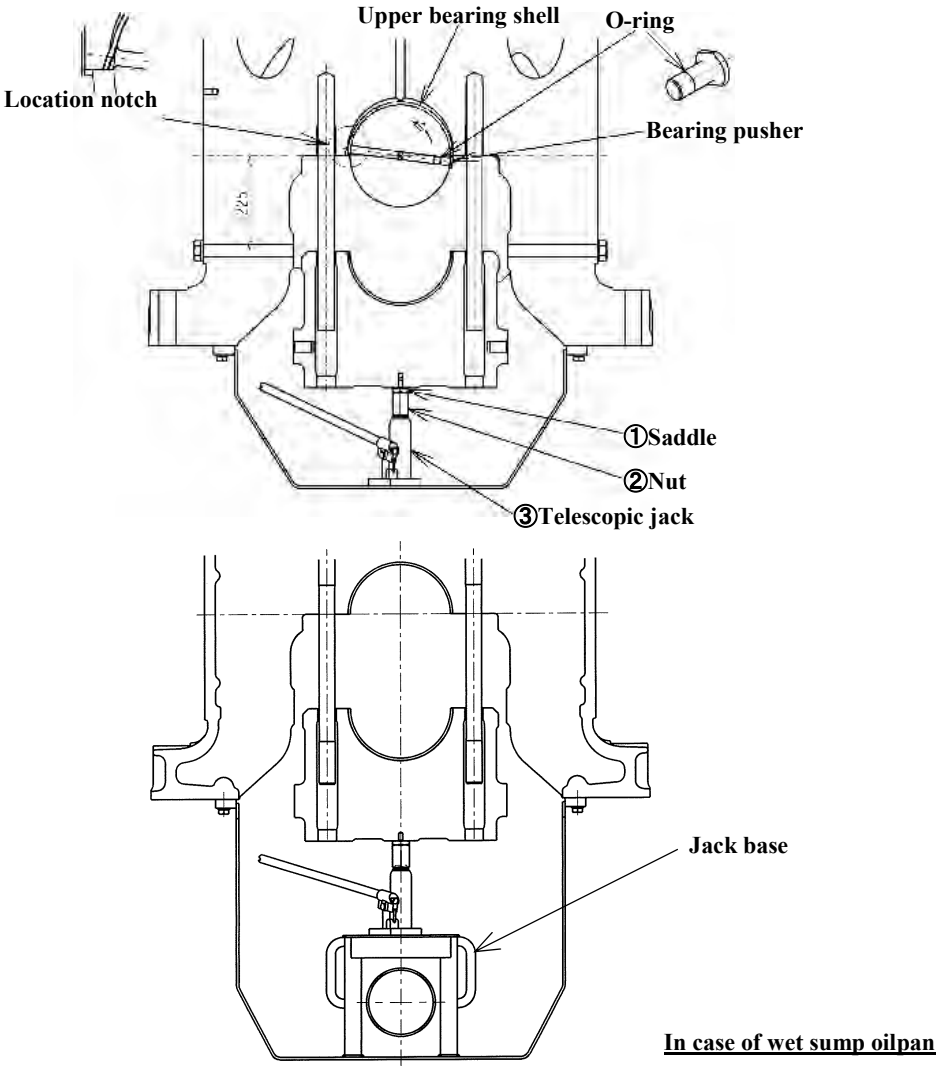
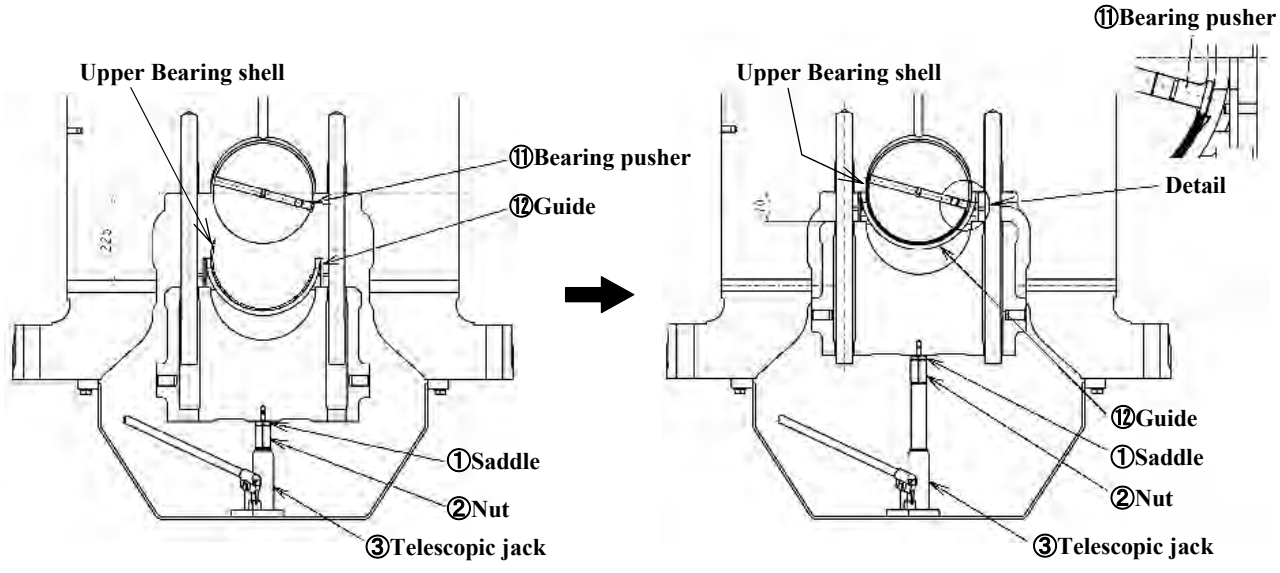


Fig.2 Upper bearing shell inserting procedure



7.5.13 Location bearing, thrust bearing check

(1) Location bearing check

(a) Disassembly

・Remove the oil flyer cover and gear case cover.

(a1) Loosen the stud nuts of location bearing. (Refer to **7.5.13** Fig.1)

(Use by hydraulic jack same as main bearing disassembly)

・Set the ④⑤⑥ hydraulic jack to two location bearing stud nuts.

・Screw the ⑥ jack bolt by hand, and then screw it until the ⑤ jack body touches lightly. At this time, make sure the top of ⑤ jack and top of location bearing cap.

・The following is same as main bearing disassembly procedure.
Refer to main bearing disassembly procedure. (Refer to WARNING and NOTE)

・Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Threads Size
Locating bearing stud	3mm	1 rotation	M42×3

(a2) Disassembly location bearing (Refer to **7.5.13** Fig.2)

・Remove the location bearing cap, and then remove upper bearing shell, thrust bearing (upper).

・Insert the ⑪ bearing pusher (with O-ring) into the crankshaft oil hole.

・Turn the crankshaft in the arrow direction, and remove the lower bearing shell.

⚠ CAUTION

(1) When turning the engine, do not insert hand and foot to gear parts. There is a danger of injuring.

(2) Before turning the engine, open the all indicator cocks surely. If not , there is very dangerous because the crankshaft may be reverse.

NOTE : When the lower bearing shell is extracted by bearing pusher, special care should be taken for operation of the turning motor. And be careful turning direction, because the bearing has a location notches.

Fig.1 Location bearing cap removing procedure

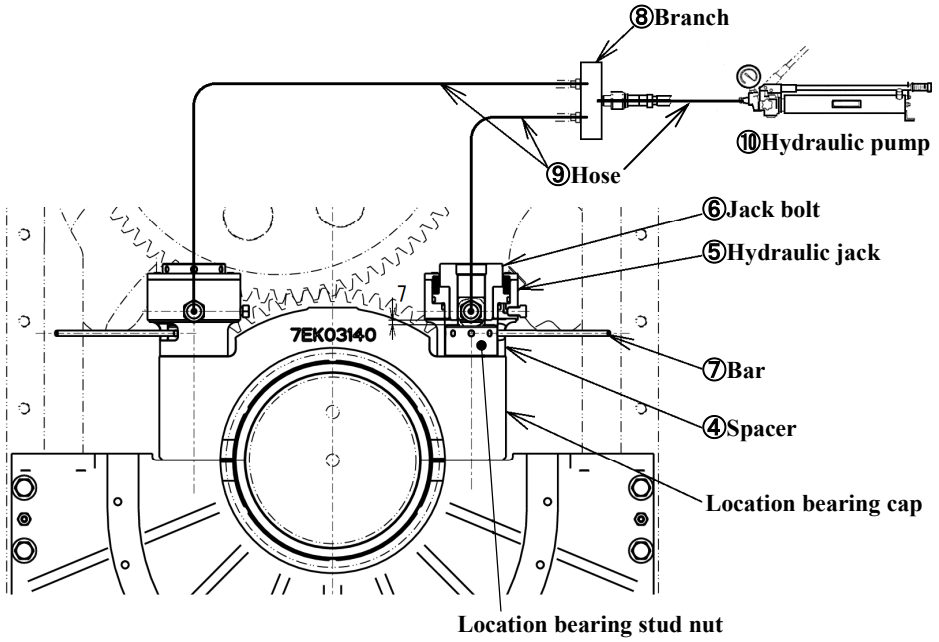
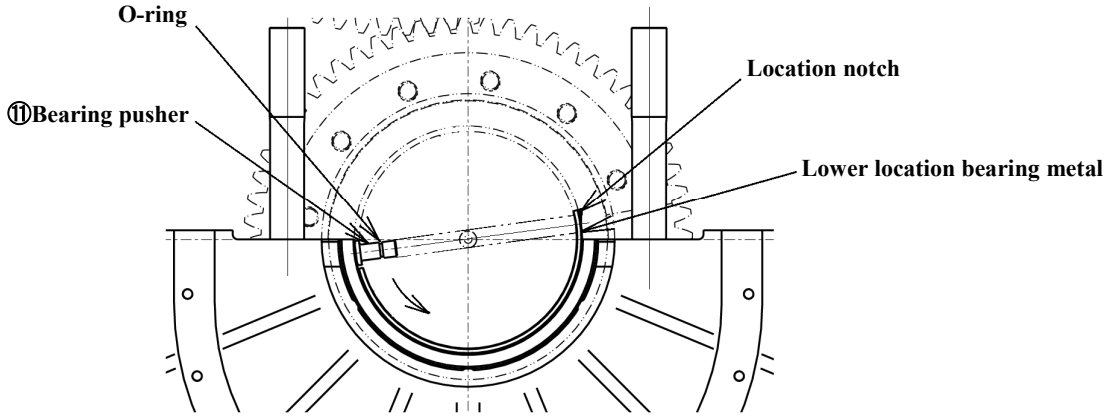


Fig.2 Lower location bearing removing procedure

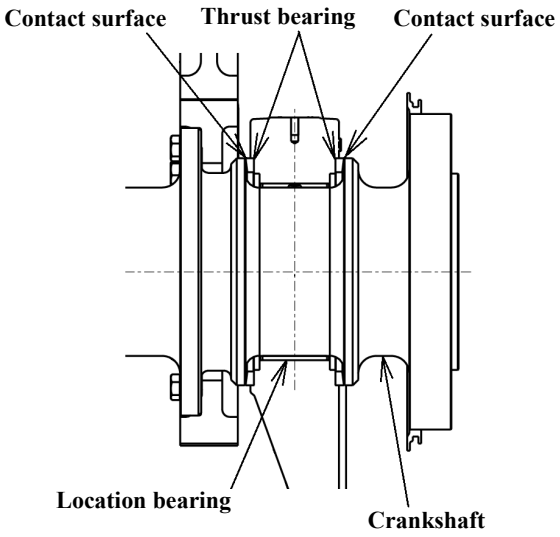


(b) Check

(b1) Check the surface condition of the location bearing (upper and lower) and thrust bearing.
Check the bearings in the same way as the crank pin bearings by referring to **7.5.2**(i).

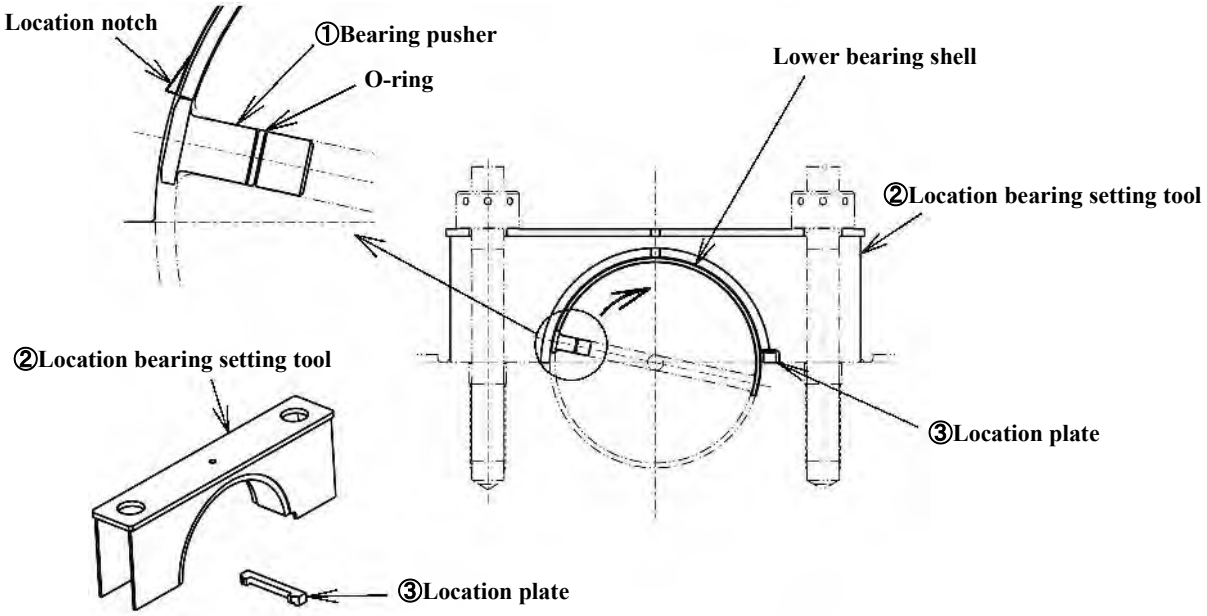
(b2) Measure the clearance between thrust bearing and crankshaft flange.

- If permissible limit over, replace the thrust bearing.
  — Refer to Paragraph **5.1** Parts adjustment standards



(c) Assembly procedure

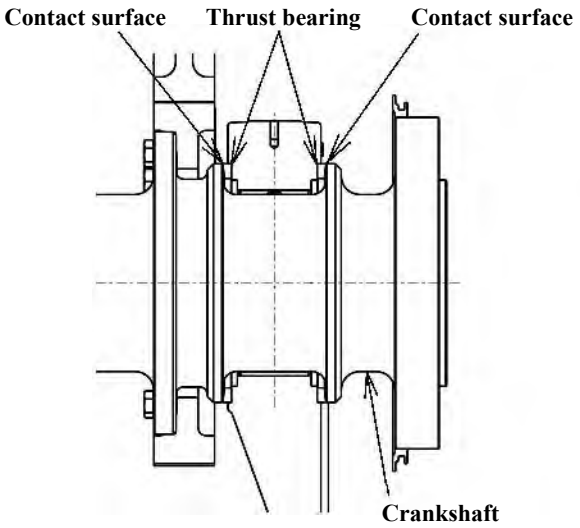
- Wash and clean the bearing shells and wipe them with dry waste cloth.
- Apply new lubricating oil on the bearing inner surface only.
- Set the ③ location plate right side as under figure.

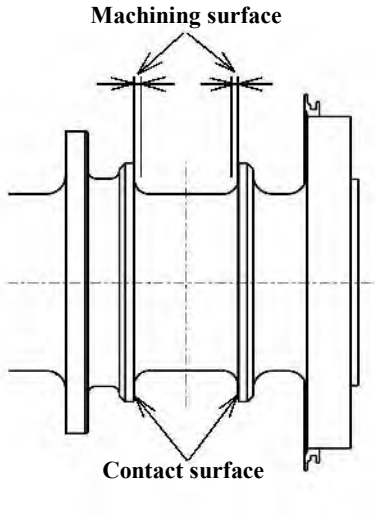


- Place the lower bearing shell on the crankshaft journal so their location notches agree, and then, insert the shell into the housing as deep as possible by hand.
- Insert the ① bearing pusher (with O-ring) into the crankshaft oil hole.
- Set the ② location bearing setting tool by location bearing stud nuts.
- Turn the crankshaft in the arrow direction to insert the lower bearing shell.
- Fit the upper bearing shell to the location bearing cap.
- Assembly procedure is carried out in the reverse order to disassembly procedure.

(2) Thrust bearing check

［Check］	［Remedy］
•Worn, damage →	Slight → Smooth with oilstone
	Seriously worn or damaged → Repair by machining → Replace thrust bearing (Oversize)





7.5.14 Crankshaft check

(a) Remove the main bearing cap, and check the crankshaft.

［**Check**］ ［**Remedy**］

・Pin and journal check

- Measure wear of crank pin → Worn (unevenly worn)
- Surface damage → Worn (unevenly worn)

Worn (unevenly worn) → Slight → Smooth with sandpaper and oilstone
Refer to Paragraph **5.1** Clearances and Wear Limit

Worn (unevenly worn) → Seriously worn or damaged → Machine to undersize

NOTE : When machining the crankshaft to undersize, special undersize bearings must be used. Be sure to consult us beforehand.

(b) Make a dye check

［**Check**］ ［**Remedy**］

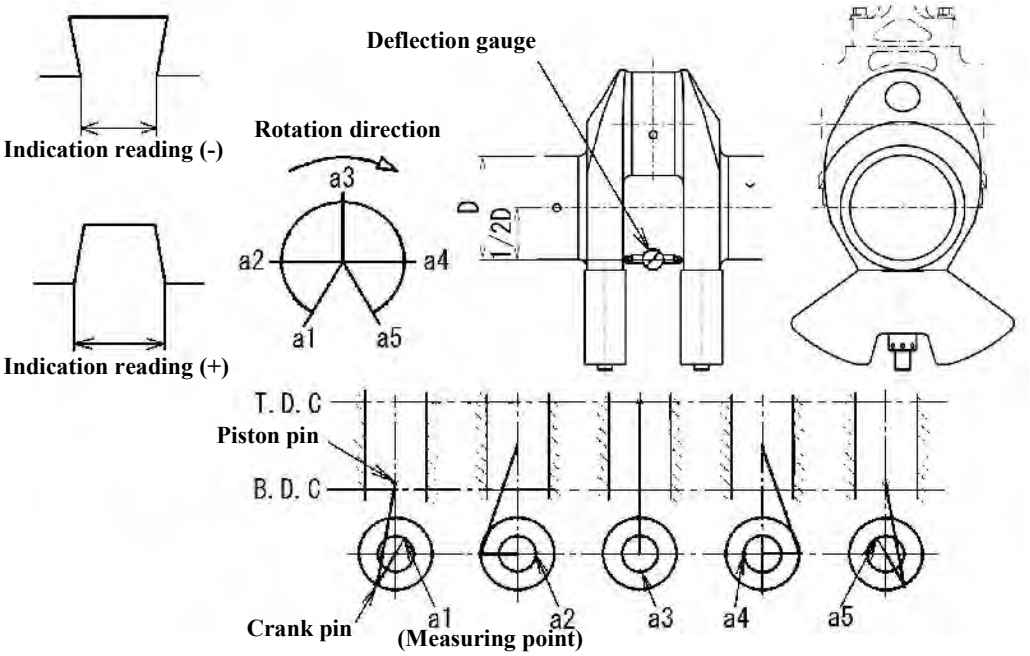
・ Crank pin outer part → Cracked → Contact our service station

(c) Crankshaft deflection measuring

—Refer to Paragraph **5.1** Parts Adjustment Standards

Depending on the measuring results, re-centering of the crankshaft.

NOTE : (1) Measure crankshaft deflection 500 hours after a new engine is put into use, or after crankshaft centering, involving bearing replace, and verify that the crankshaft is free of deflection.
(2) Measure the deflection when engine is cold.
(3) When crank arm is closed, the gauge will show positive value, and when crank arm is opened, the gauge will show negative value. (Refer to under figure)



7.5.15 Crankshaft torsional damper check

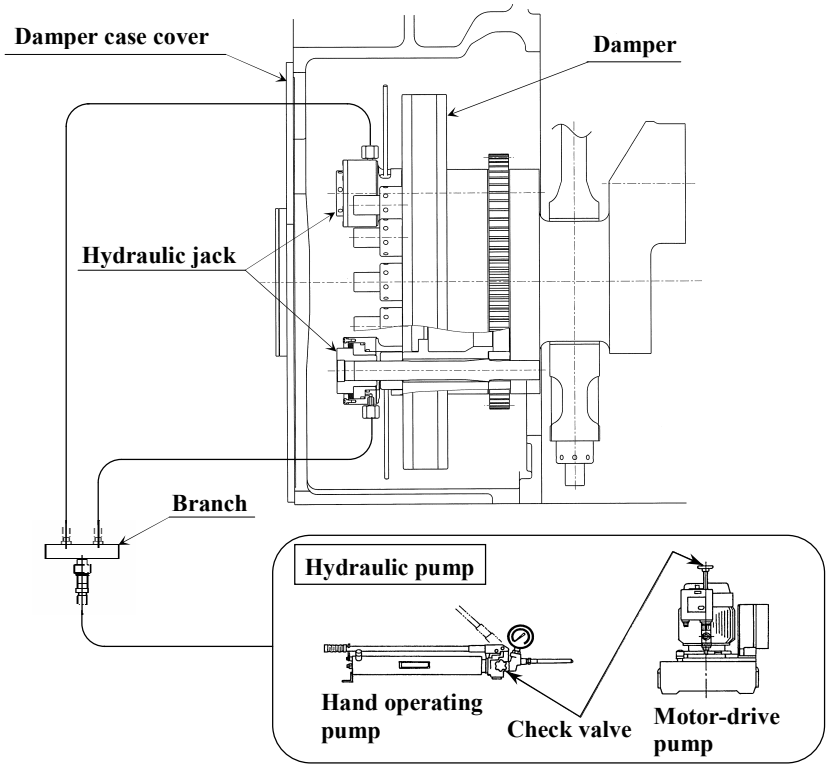
(a) Disassembly procedure

- Remove the damper case cover.
- Loosen the stud nuts by hydraulic jack.
- After hanging by lifting wire, remove the temporary bolts, and pull out the damper from the damper case.

- Loosing amount of stud nut

	Loosing Amount	Rotating Angle	Threads Size
Damper stud	3mm	1 rotation	M42×3

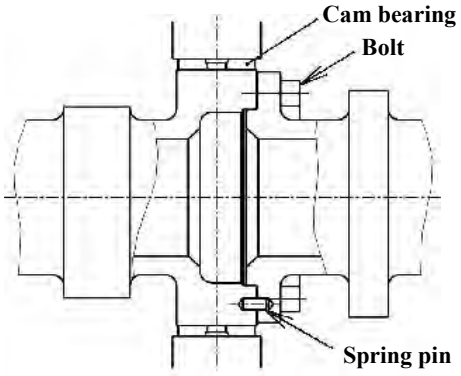
NOTE : Refer to the manufacturer's instruction manual as to check the geislinger damper.



7.5.16 Cam bearing, thrust bearing check

(a) Disassembly procedure

- Remove cam case cover.
- Remove cam gear cover, fuel injection pumps, intake and exhaust valve gear
- Loosen the fitting bolts of the thrust washer on idle gear, and then remove the idle gear.
- Loosen the cam gear bolts, and remove the cam gear.
- Apply new lubricating oil on all of bearings inner surface.
- Loosen the fitting bolts of the cam shaft, and then remove the cam shaft from driving end.



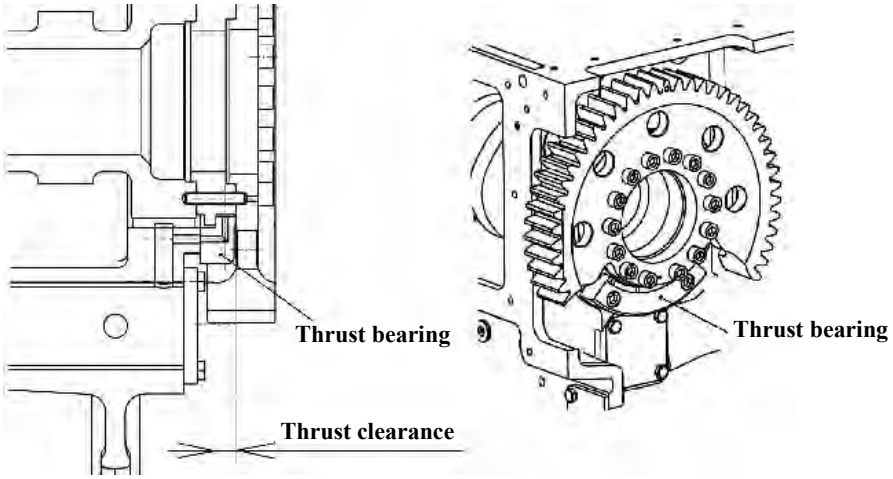
(b) Check

(b1) Clearance check

[Check]	[Probable Cause]	[Remedy]
• Excessive clearance		→ Replace bearing
• Inside surface peeled	→ Lubrication faulty	→ Replace bearing
		→ Check lubricating oil system
	→ Lubricating oil deteriorated	→ Analyze lubricating oil

(b2) Thrust bearing check

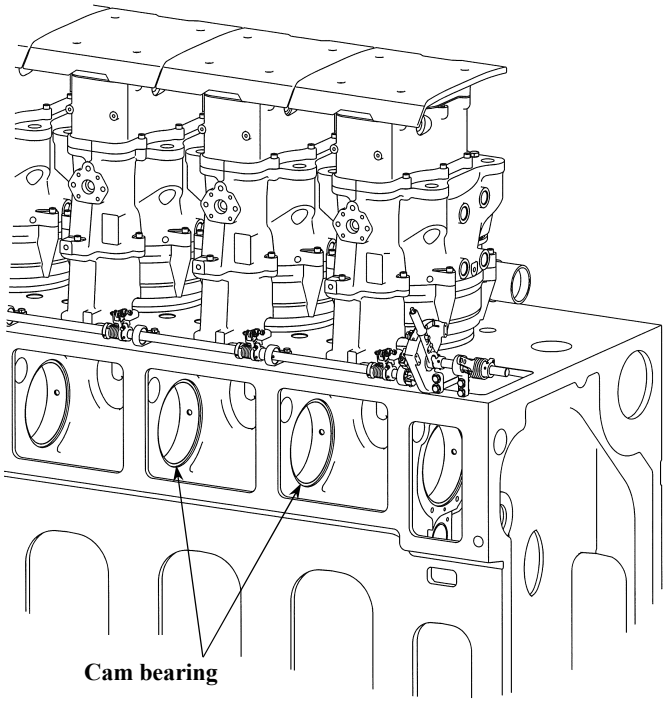
- Thrust clearance excessive large → Replace if necessary
  Refer to Paragraph **5.1** Clearance and Wear Limit



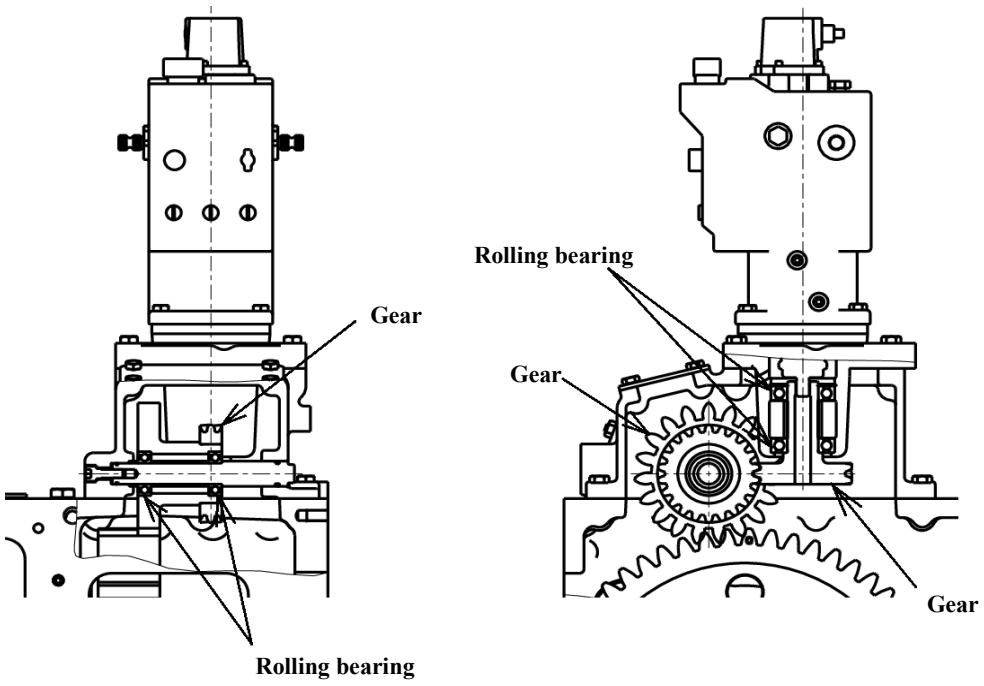
(c) Reassemble procedure

Assembly procedure is carried out in the reverse order to disassembly procedure.

- Wash and clean the bearings, and wipe them with dry waste cloth.
- Apply new lubricating oil on the bearing inner surface only.
- Insert the cam shaft.
- Keep cam shaft flange out of the cylinder block.
- Adjusts the phase of flange with the position nock pin, tighten up bolts.
- Assemble the cam gear after camshaft finished assembly.
- Assemble the driving end idle gear.
- Tighten up bolts a diagonal line.
- Refer to paragraph **5.2** Tightening Specification of Main Parts.



7.5.17 Governor driving device check



［Check］ ［Remedy］

•Gear surface pitted → Slight → Smooth with oilstone
→ Serious → Replace gear

NOTE : When changing the bevel gear, be sure replace a pair (driving and driven gear).

［Check］ ［Probable Cause］ ［Remedy］

•Gear backlash incorrect → Gear worn → Slight → Repair
Refer to Paragraph **5.1** Clearance and Wear Limit → Serious → Replace

→ Rolling bearing worn → Slight → Repair
→ Serious → Replace

7.5.18 Governor, governor linkage, Fuel linkage check

(1) Governor check

(a) Remove the governor from governor linkage, and send to Governor Maker for check.

NOTE : When removing serration part, pull out perpendicularly to shaft. Be careful, don't damage serration part.

(b) Changing of governor oil

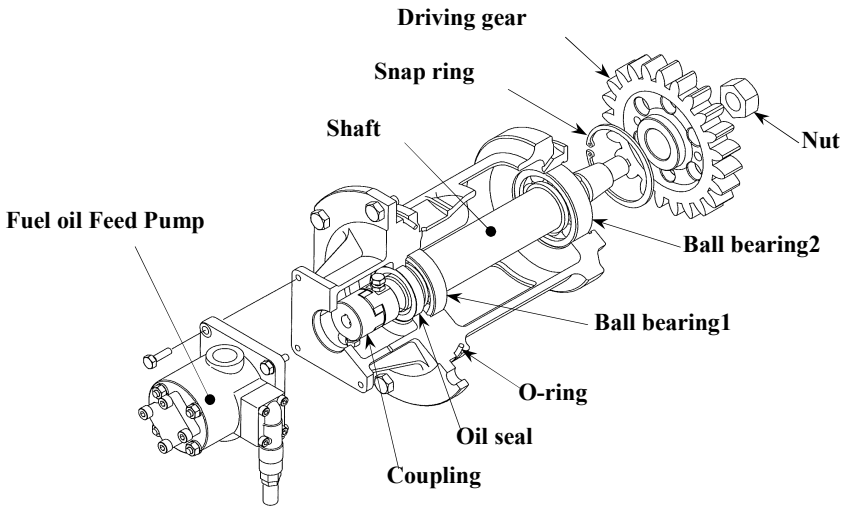
— Refer to the Instruction Manual for Hydraulic Governor.

(2) Governor linkage, Fuel linkage check

[Check]	[Probable cause]	[Remedy]
•Linkage action not smooth	Link pin worn	Replace
	Link pin stick	Replace
	Bearing or ball bearing stick	Replace
	Bearing or ball bearing eccentricity	Repair
	Deformed, damaged	Replace
	Bearing or ball bearing worn	Replace
• Linkage excessive loose	Link pin worn	Replace
	Bearing worn	Replace
• Spring action not smooth	Bearing worn	Replace
	Bearing stick	Replace
	Spring stick	Replace
• Rack lever excessive loosened (forked part)	Forked part worn	Replace

NOTE : If linkage has excessive looseness, shall be occur hunting. Make sure replace necessary parts.

7.5.19 Fuel oil feed pump check



(a) Disassembly procedure

- Remove the driving device of the fuel oil feed pump from the gear case.
- Remove the fuel oil feed pump from driving device.
- Loosen the nut and remove the driving gear from shaft.
- Remove the coupling and snap ring, pull out the shaft.

(b) Check

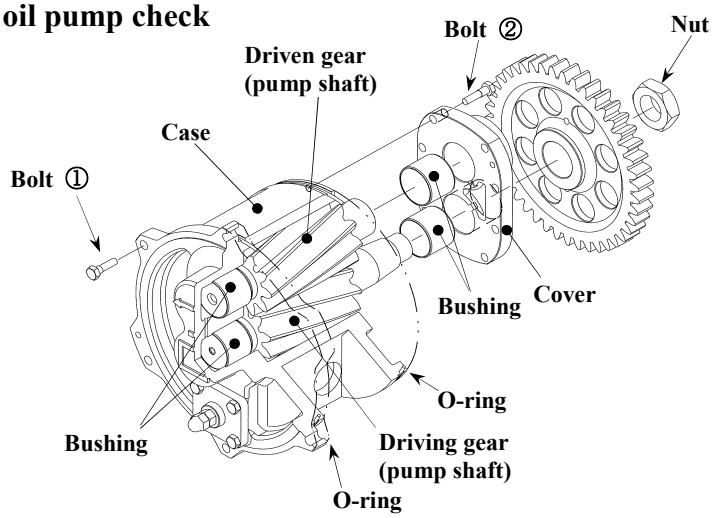
[Check]	[Probable Cause]		[Remedy]
(b1) Gear surface pitted		Slight	Smooth with oilstone
		Serious	Replace gear
(b2) Gear backlash incorrect Refer to **5.1** Adjustment Standards for Main Parts	Gear worn	Slight	Repair
		Serious	Replace
	Ball bearing worn	Slight	Repair
		Serious	Replace

(c) Reassemble procedure

Reassembling is carried out in the reverse order to overhaul

- Replace the o-ring and oil seal.
- Replace the coupling if necessary.

7.5.20 Lubricating oil pump check



(a) Disassembly

- Loosen the ① bolt and remove the lubricating oil pump from gear case.
- Loosen the nut and remove the driving gear from shaft.
- Loosen the bolt ② and remove the cover.
- Remove the pump gear. (driving and driven gear)

(b) Check

(b1) Pump gear

[Check]	[Probable Cause]	[Remedy]
• Gear surface pitted	Slight	Smooth with oilstone
	Serious	Replace gears
	Pump shaft worn bushing	Replace bushing

NOTE : When changing the gear, be sure replace a pair (driving and driven gear).

• Gear circumference in contact with case		Repair Refer to Paragraph **5.1** Clearance and Wear Limit
	Pump shaft worn bushing	Replace bushing
•Foreign matter	Suction filter faulty	Check suction filter Check gear surface
•Check gear backlash		Repair if necessary

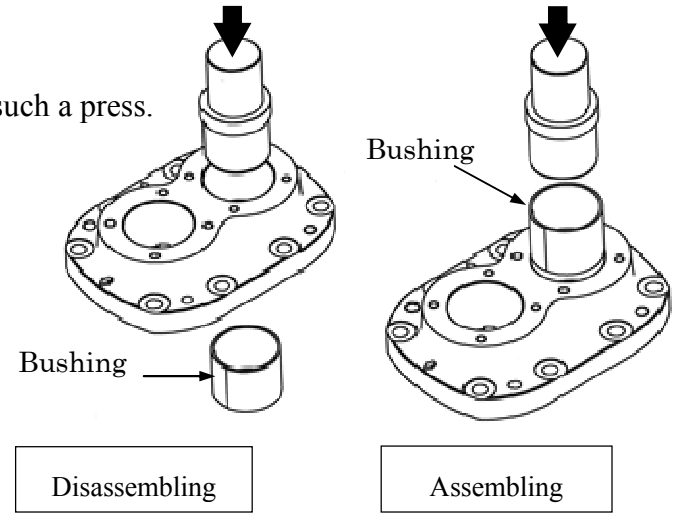
(b2) Measure shaft bushing wear

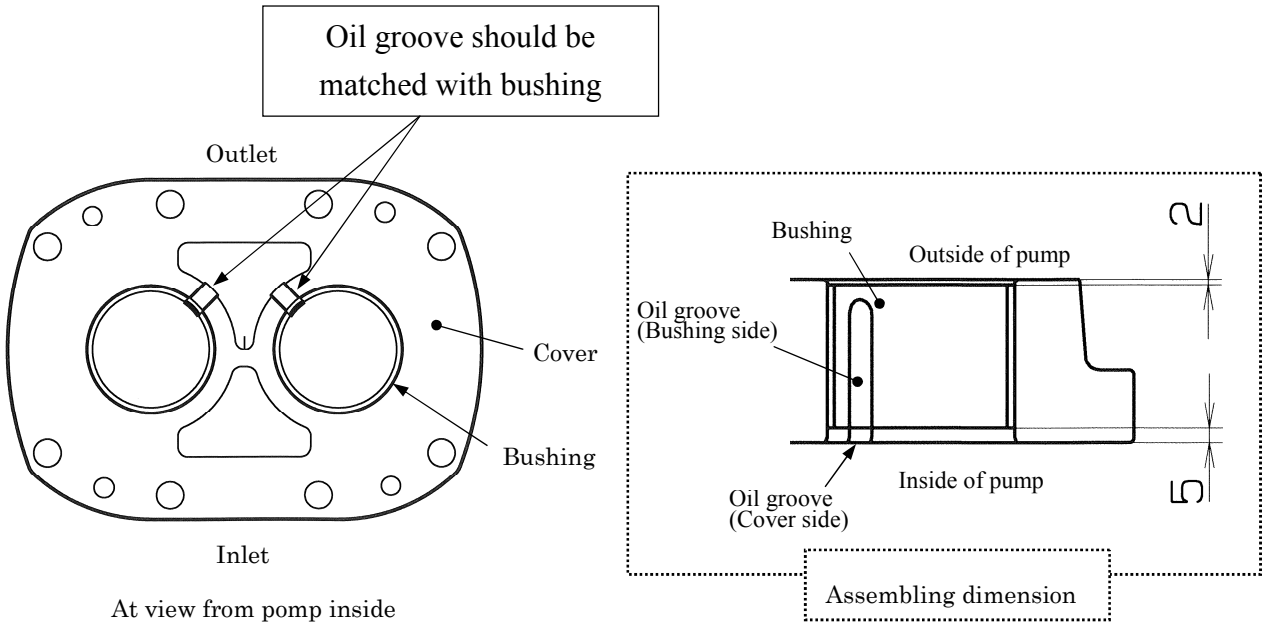
•Faulty contact or rough surface	Smooth with sandpaper, or replace Refer to Paragraph **5.1** Clearance and Wear Limit

(c) Instruction of assembling and disassembling bushing

・Disassembling
Please remove bushing vertically by using such a press.

・Assembling
Please insert bushing vertically and
oil groove should be matched with bushing
like below

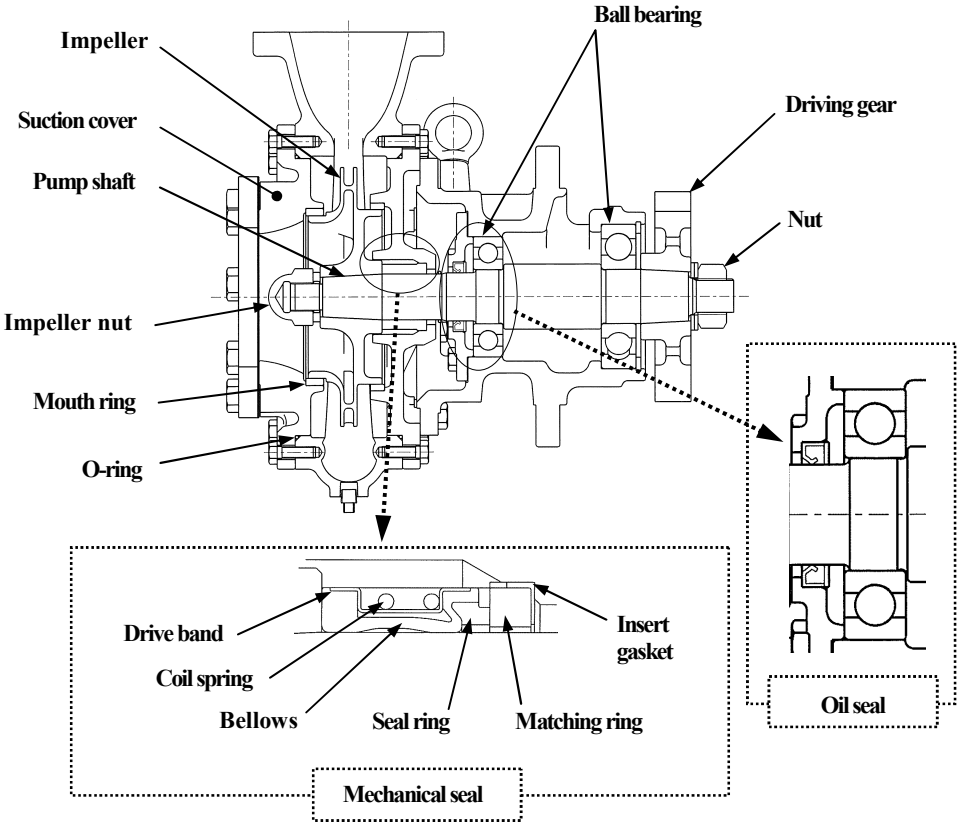




(d) Re-assembling

・Reassemble in the reverse procedure of disassembly
・All O-rings should be replaced to new.
・Please tighten the nut for drive gear with applying Loctite 243 by specified torque
-Refer to 5.2 Tightening Specification of Main Parts.

7.5.21 Cooling water pump check



(a) Disassembly procedure

- Remove the cooling water piping and take out the cooling water pump.
- Remove the suction cover, impeller nut and take out the impeller.
- Take out the mechanical seal. Be careful, don't damage shaft part.
- Loosen the nut and remove the driving gear.
- Pull out the shaft from the pump case and remove the ball bearing and oil seal.

(b) Check

- Impeller and mouse ring.

[Check]	[Probable Cause]	[Remedy]
Sliding part worn	⟶	If permissible limit over, replace the impeller and mouse ring. Refer to **5.1** Adjustment Standards for Main Parts

- Impeller, Pump case, Suction cover

Cavitation, erosion	Slight ⟶	Repair with sand paper
	Serious ⟶	Replace

(c) Reassemble

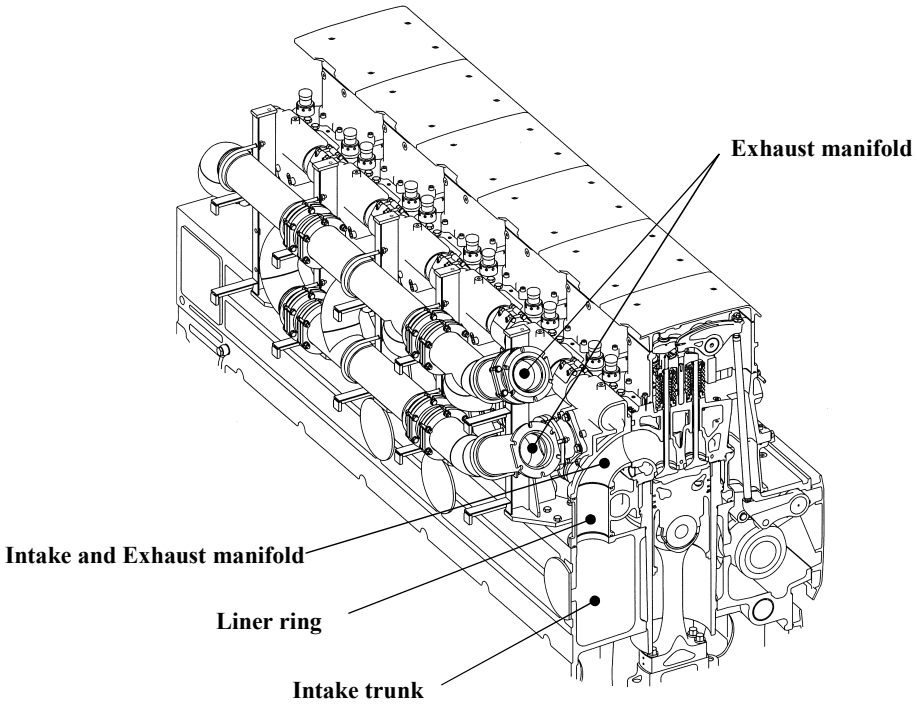
- Remove the dirt and rust by washing.
- Assemble the exhaust valve in the sequence opposite to that disassembly. Replace the following part whenever the cooling water pump are disassembled.
  - Mechanical seal
  - Oil seal
  - Ball bearing
- Mechanical seal setting procedure
  ① After insert the pump shaft, unitize the insert gasket and matching ring.
  ② Apply the fresh water on the circumference surface. Set in the pump case.
  ③ Apply the liquid detergent to the bellows interior surface and pump shaft. Push the pump shaft into the bellows carefully.
- Apply LOCTITE 242 to the impeller nut and driving gear nut. Tighten with regulation torque.
  Refer to **5.2** Tightening Specification of Main Parts.

7.5.22 Exhaust manifold check

[Check]	[Remedy]
•Lagging damaged	→ Repair
•Piping deformed	→ Repair
•Piping cracked or corroded	→ Repair or replace
•Bracket loosened	→ Replace
•Expansion joint damaged	→ Replace

7.5.23 Intake manifold and intake trunk check

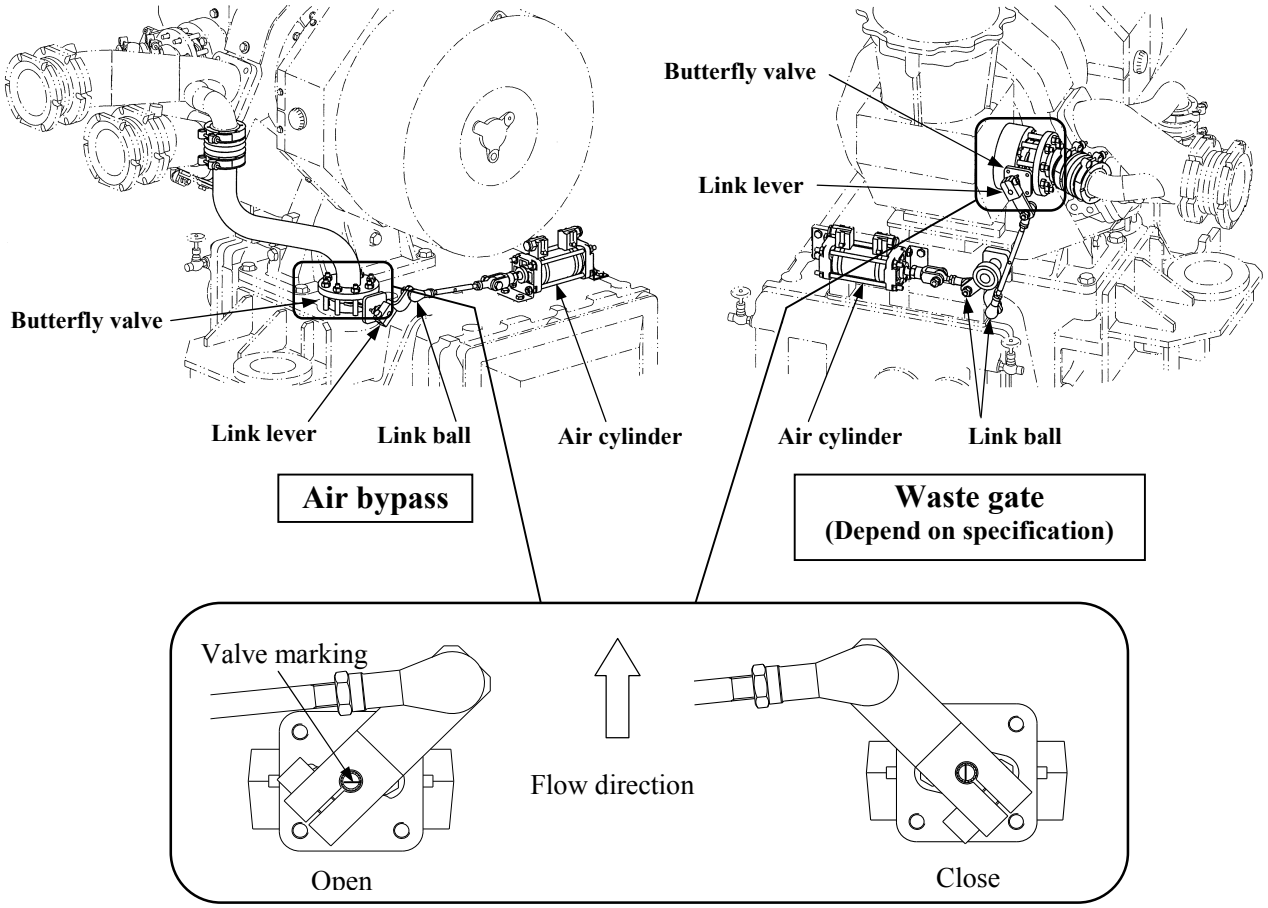
[Check]	[Remedy]
•Intake duct broken	→ Repair or replace
•Intake manifold inside check and cleaning	



7.5.24 Air bypass and Waste gate check.

(a)Disassembly procedure

- Remove the link connecting the air cylinder, shaft and butterfly valve.
- Remove the butterfly valve and lagging of the expansion joint.
- Remove the nut that secures the butterfly valve and piping flange.



NOTE : (1) When disassembling the butterfly valve, pull out the link lever so as not to damage the serration at the stem.

(2) Opened when the valve body mark of the butterfly valve is parallel to the flow direction, closed when it is perpendicular to the flow direction please confirm that it becomes.

(b) Check

[Check]	[Probable Cause]	[Remedy]
Butterfly valve		
• Check valve marking position	⟶	Repair or replace
• Check valve working smooth	⟶	Repair or replace
• Check the leak from bearing	⟶	Repair or replace

Air cylinder and linkage

- Linkage action not smooth → Insufficient lubrication of the moving part → Grease-up of the moving part
- Linkage excessive loose → Link ball worn → Replace
  - → Reamer bolt worn → Replace
  - → Link lever worn → Replace
  - → Ball bearing worn → Replace
- Control air piping rubber hose crack → Aging deterioration → Replace
- Air cylinder movement is not smooth → Insufficient lubrication
- Air cylinder air leaks → Air seal worn → Replace

(c) Reassembly procedure

・Assembly procedure is carried out in the reverse order to disassembly procedure.

7.5.25 Cooler check

(a) Lubricating oil cooler, jacket water cooler

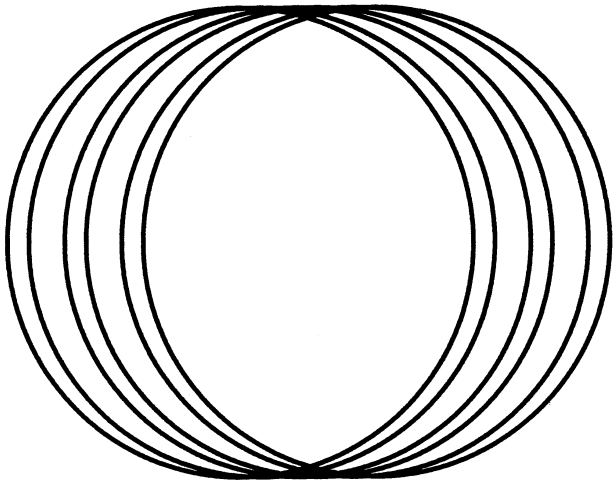
(b) Check

[Check]	[Remedy]
• Inside Cleaning	Disassemble and clean
• O ring check	Replace
• Pressure test after assembly	
→ Jacket water cooler	Test pressure : 0.45 MPa
→ Lubricating oil cooler	Test pressure : 1.00 MPa

7.5.26 Remote control device check

Refer to the Instruction Manual for Remote Control Device.

MEMO



NIIGATA DIESEL INSTRUCTION MANUAL

MG(L)28AHX

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8. TROUBLESHOOTING

The purpose of troubleshooting is investigating the fundamental causes of troubles and preventing the reoccurrence of the same trouble after repairs are made.

In troubleshooting, an intimate knowledge of the mechanism of the device and its operating principle is of essential importance. With this knowledge, you can check the various functions in the proper sequence and locate the cause.

8.1 Procedures Before Investigating the Cause of Trouble

8.1.1 Early detection of troubles

Engine failure is usually preceded by certain signs. Therefore, whenever even a minor or negligible abnormality is observed, the suspected parts must be immediately checked for early detection of the trouble area and for minimizing accidents.

8.1.2 Preliminary work

Before attempting troubleshooting, keep watch for the following and make a complete study of the parts involved.

- Was there an alarm before the trouble occurred?
- Had there been a similar trouble in the past?
- What repairs and maintenance work done before?
- Is it safe to continue operation while troubleshooting?

8.1.3 Investigating the cause

Begin investigation of the cause with simple items: First check those easy and obvious, then proceed to those complicated gradually to save time.

8.1.4 Re-inspection before overhaul

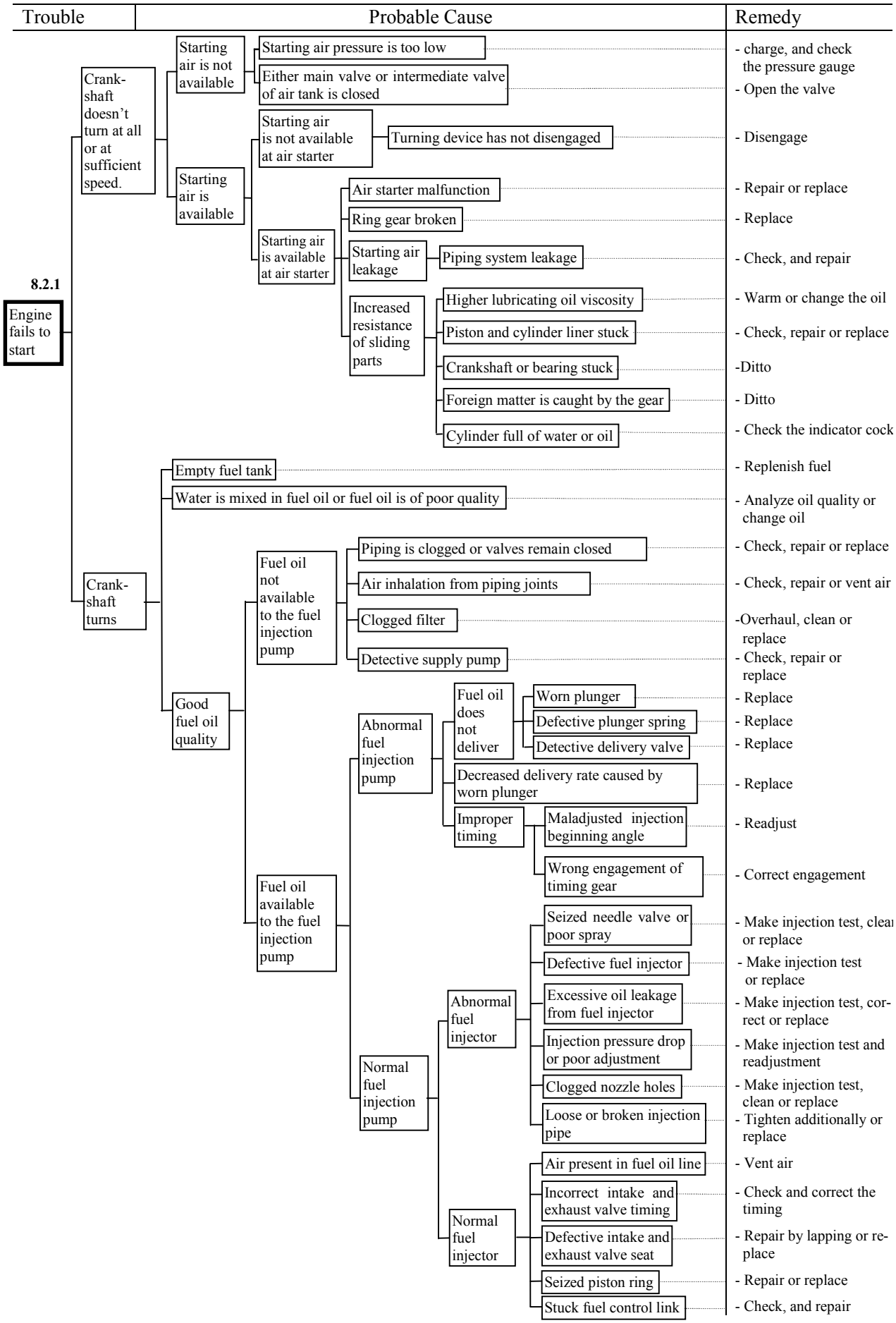
In many cases, a trouble may be related to not only one part but to other parts as well. Carry out an additional inspection before disassembling the device to confirm that the approach is correct and to prevent missing of evidence in related parts.

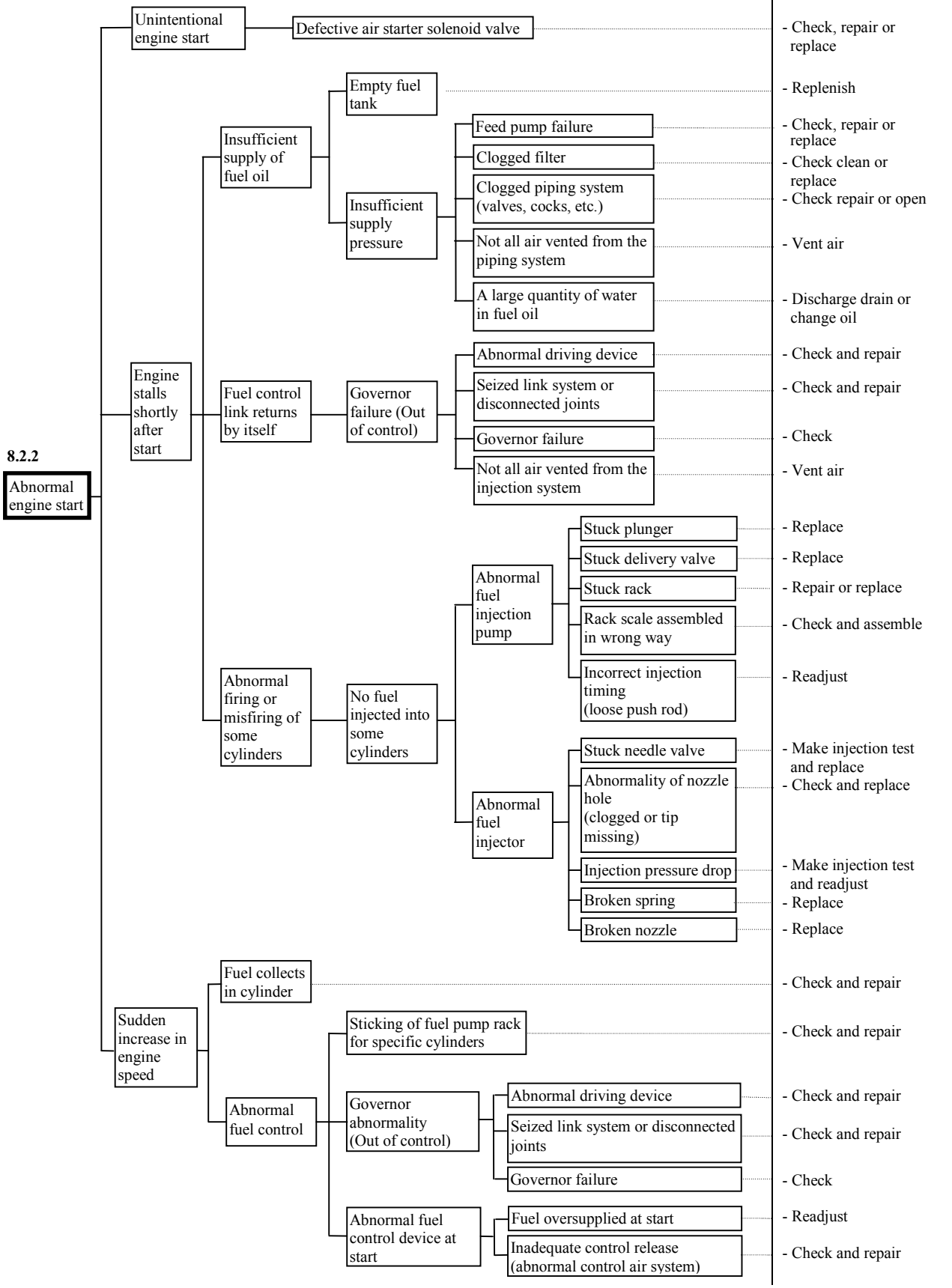
8.1.5 Correcting the sources of problems

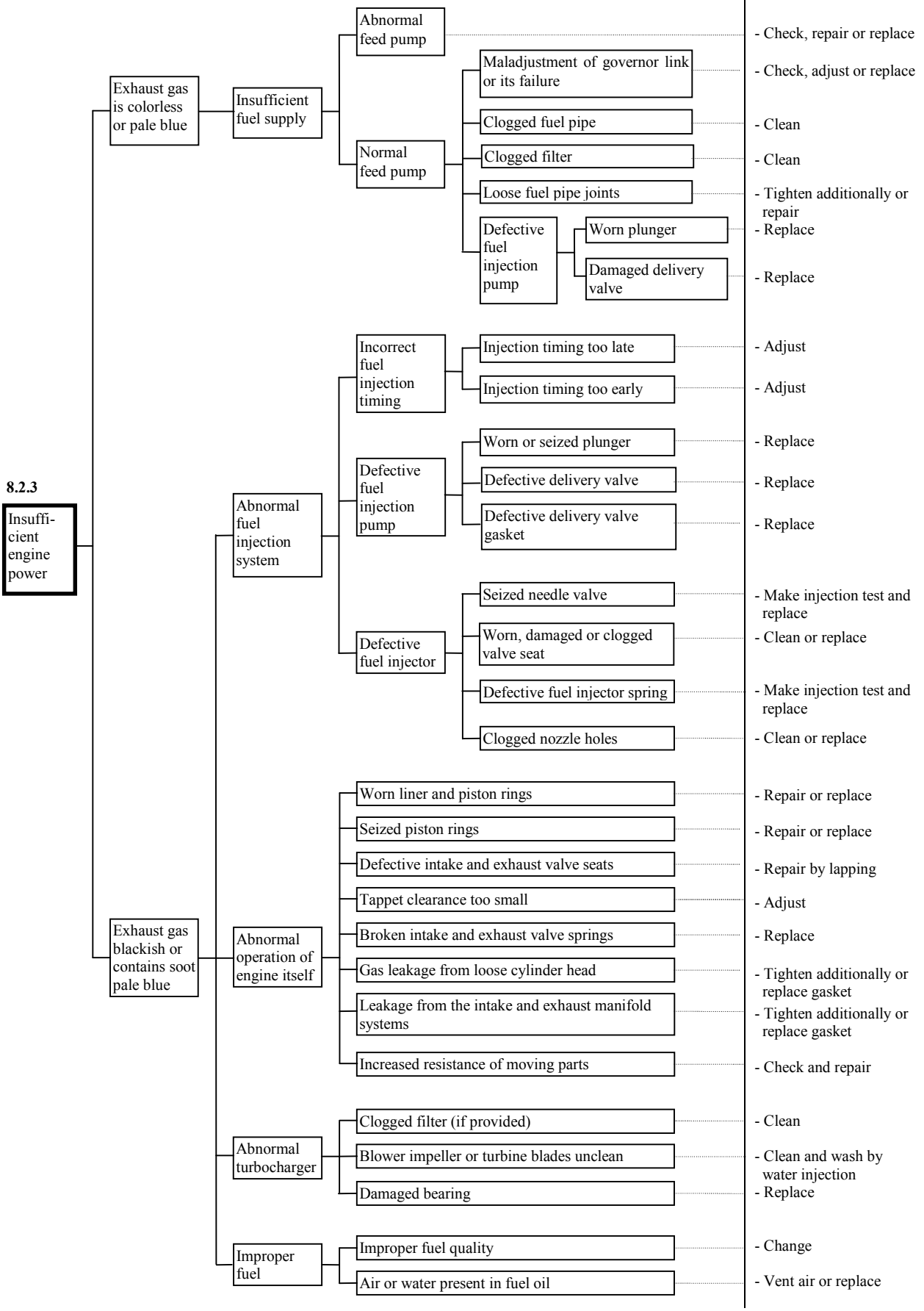
Make it a rule to not only remedy the trouble but to identify the cause of the trouble. For example, a stuck fuel injection pump plunger can be remedied by repairing the plunger or replacing it with a new one. However, the cause of the trouble remains yet to be eliminated.

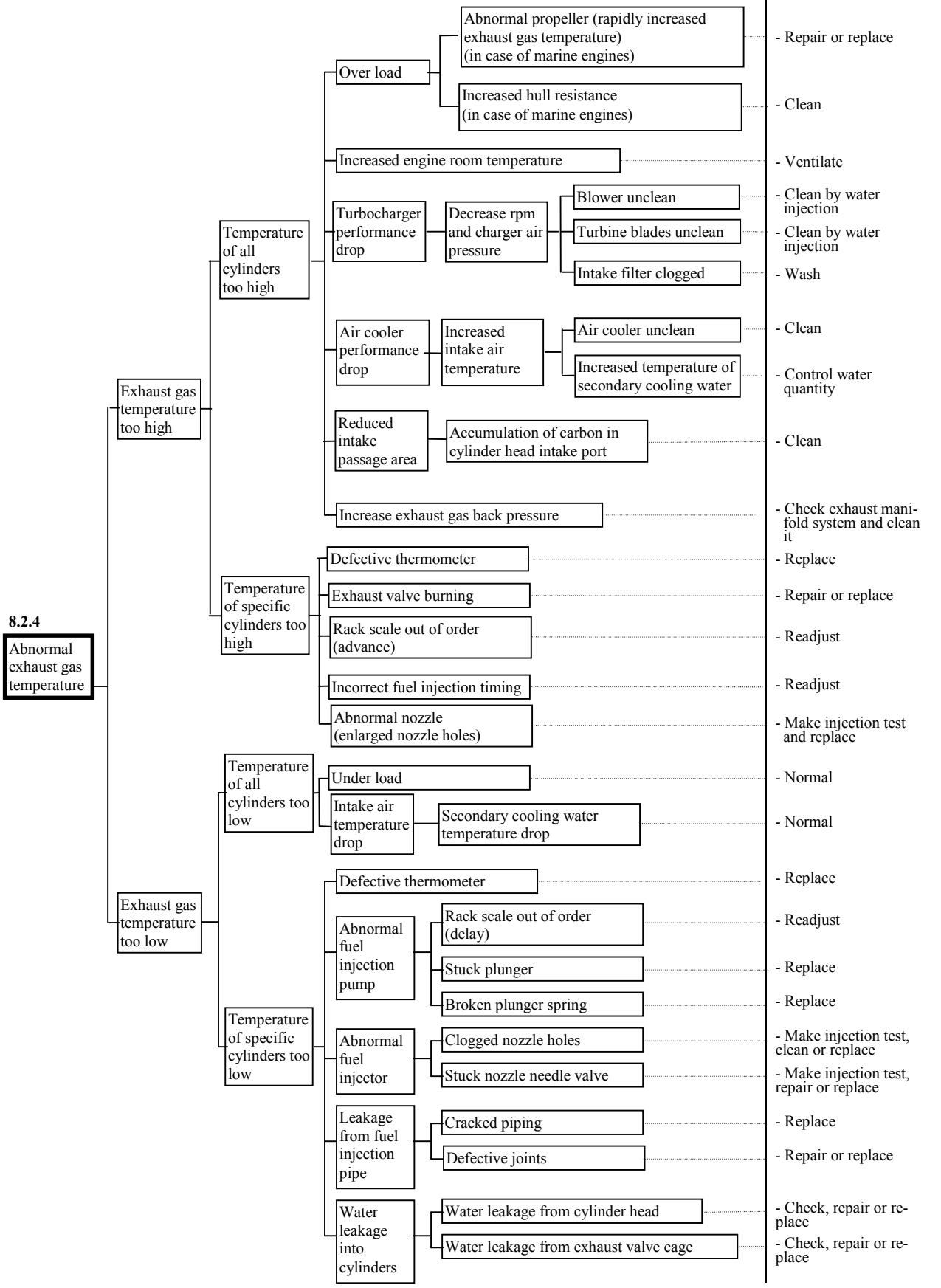
8.2 Causes of Troubles and Countermeasures

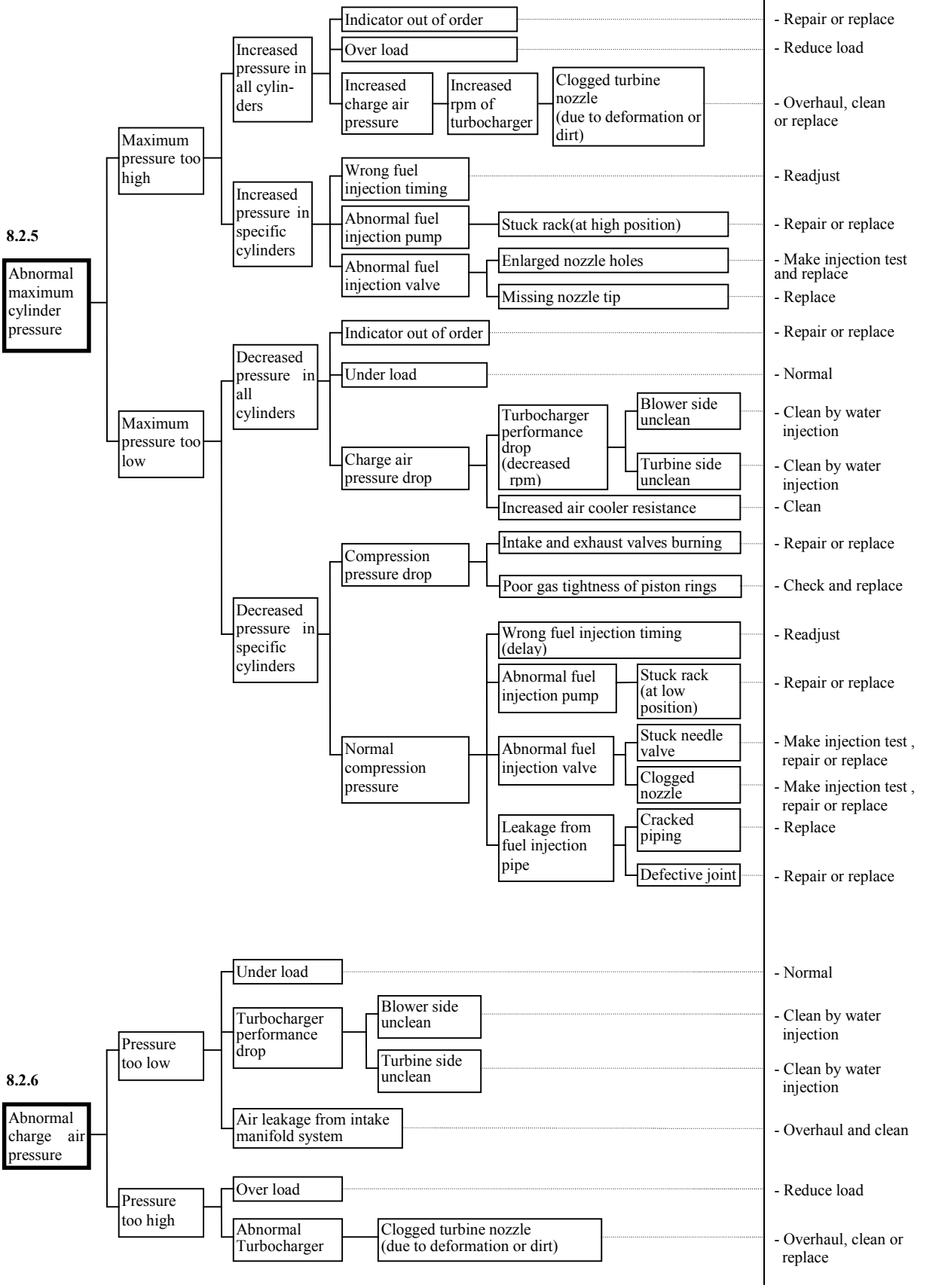
The following chart gives a listing of probable troubles during diesel engine operation and their causes as well as remedies against them. It should be borne in mind that the chart does not provide answers to all possible cases.

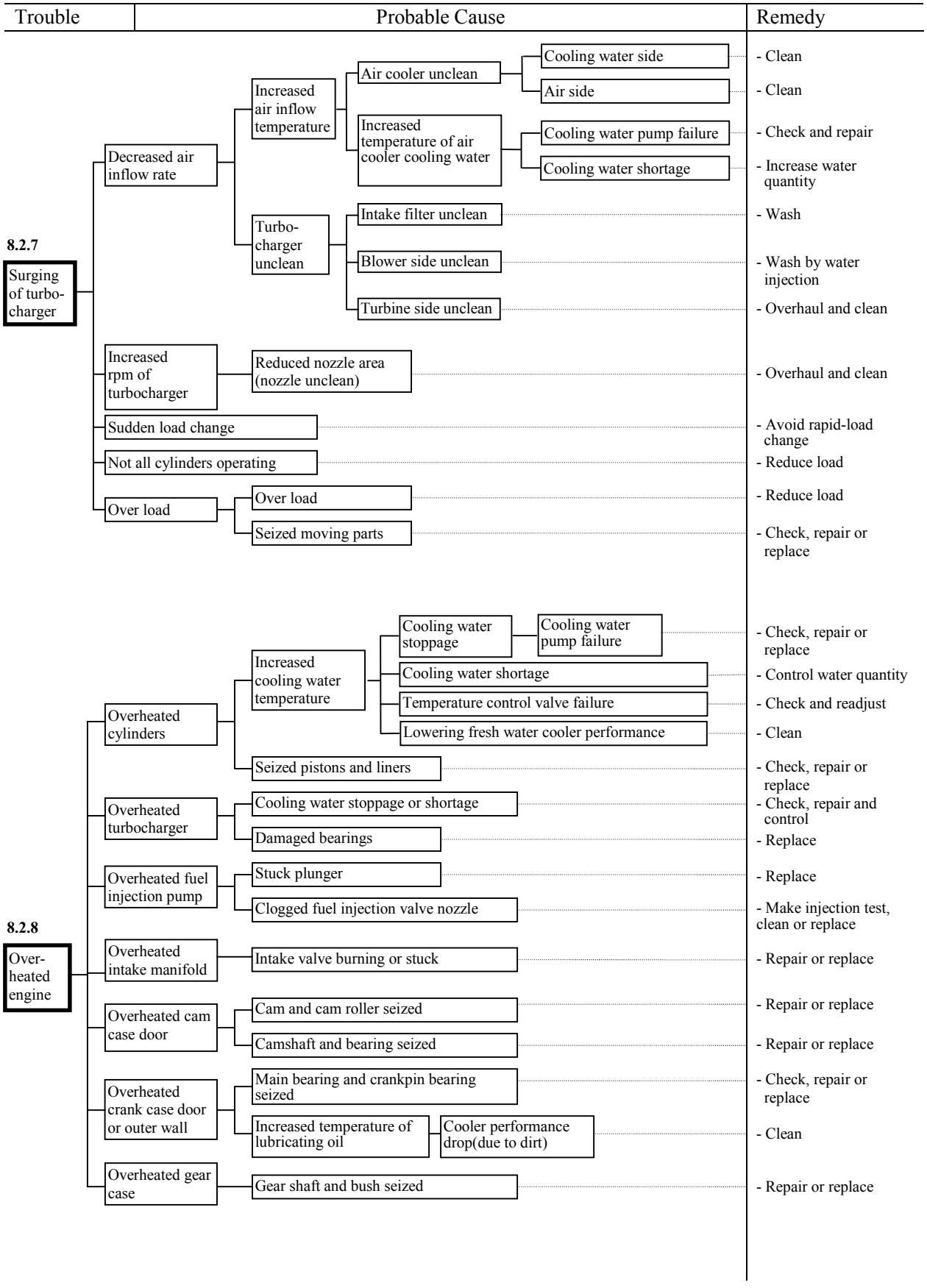

Trouble
Probable Cause
Remedy
8.2.1
Engine fails to start
Crank-shaft doesn't turn at all or at sufficient speed.
Starting air is not available
Starting air pressure is too low
- charge, and check the pressure gauge
Either main valve or intermediate valve of air tank is closed
- Open the valve
Starting air is available
Starting air is not available at air starter
Turning device has not disengaged
- Disengage
Starting air is available at air starter
Air starter malfunction
- Repair or replace
Ring gear broken
- Replace
Starting air leakage
Piping system leakage
- Check, and repair
Increased resistance of sliding parts
Higher lubricating oil viscosity
- Warm or change the oil
Piston and cylinder liner stuck
- Check, repair or replace
Crankshaft or bearing stuck
-Ditto
Foreign matter is caught by the gear
- Ditto
Cylinder full of water or oil
- Check the indicator cock
Crank-shaft turns
Empty fuel tank
- Replenish fuel
Water is mixed in fuel oil or fuel oil is of poor quality
- Analyze oil quality or change oil
Good fuel oil quality
Fuel oil not available to the fuel injection pump
Piping is clogged or valves remain closed
- Check, repair or replace
Air inhalation from piping joints
- Check, repair or vent air
Clogged filter
-Overhaul, clean or replace
Detective supply pump
- Check, repair or replace
Fuel oil available to the fuel injection pump
Abnormal fuel injection pump
Fuel oil does not deliver
Worn plunger
- Replace
Defective plunger spring
- Replace
Detective delivery valve
- Replace
Decreased delivery rate caused by worn plunger
- Replace
Improper timing
Maladjusted injection beginning angle
- Readjust
Wrong engagement of timing gear
- Correct engagement
Normal fuel injection pump
Abnormal fuel injector
Seized needle valve or poor spray
- Make injection test, clean or replace
Defective fuel injector
- Make injection test or replace
Excessive oil leakage from fuel injector
- Make injection test, correct or replace
Injection pressure drop or poor adjustment
- Make injection test and readjustment
Clogged nozzle holes
- Make injection test, clean or replace
Loose or broken injection pipe
- Tighten additionally or replace
Normal fuel injector
Air present in fuel oil line
- Vent air
Incorrect intake and exhaust valve timing
- Check and correct the timing
Defective intake and exhaust valve seat
- Repair by lapping or replace
Seized piston ring
- Repair or replace
Stuck fuel control link
- Check, and repair

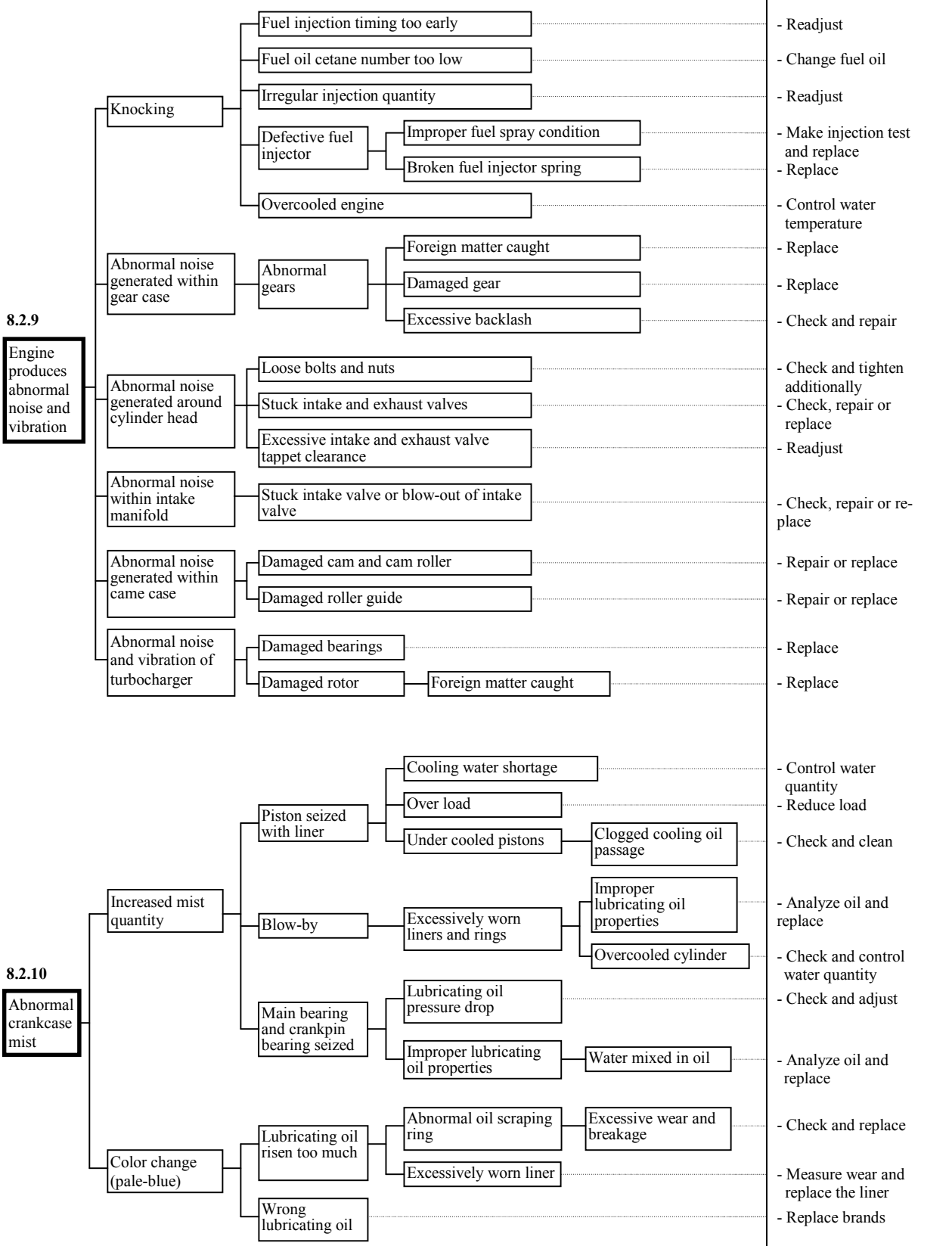

Trouble
Probable Cause
Remedy
8.2.2
Abnormal engine start
Unintentional engine start
Defective air starter solenoid valve
- Check, repair or replace
Engine stalls shortly after start
Insufficient supply of fuel oil
Empty fuel tank
- Replenish
Insufficient supply pressure
Feed pump failure
- Check, repair or replace
Clogged filter
- Check clean or replace
Clogged piping system (valves, cocks, etc.)
- Check repair or open
Not all air vented from the piping system
- Vent air
A large quantity of water in fuel oil
- Discharge drain or change oil
Fuel control link returns by itself
Governor failure (Out of control)
Abnormal driving device
- Check and repair
Seized link system or disconnected joints
- Check and repair
Governor failure
- Check
Not all air vented from the injection system
- Vent air
Abnormal firing or misfiring of some cylinders
No fuel injected into some cylinders
Abnormal fuel injection pump
Stuck plunger
- Replace
Stuck delivery valve
- Replace
Stuck rack
- Repair or replace
Rack scale assembled in wrong way
- Check and assemble
Incorrect injection timing (loose push rod)
- Readjust
Abnormal fuel injector
Stuck needle valve
- Make injection test and replace
Abnormality of nozzle hole (clogged or tip missing)
- Check and replace
Injection pressure drop
- Make injection test and readjust
Broken spring
- Replace
Broken nozzle
- Replace
Sudden increase in engine speed
Fuel collects in cylinder
- Check and repair
Abnormal fuel control
Sticking of fuel pump rack for specific cylinders
- Check and repair
Governor abnormality (Out of control)
Abnormal driving device
- Check and repair
Seized link system or disconnected joints
- Check and repair
Governor failure
- Check
Abnormal fuel control device at start
Fuel oversupplied at start
- Readjust
Inadequate control release (abnormal control air system)
- Check and repair


Trouble
Probable Cause
Remedy
8.2.3
Insuffi-cient engine power
Exhaust gas is colorless or pale blue
Insufficient fuel supply
Abnormal feed pump
- Check, repair or replace
Normal feed pump
Maladjustment of governor link or its failure
- Check, adjust or replace
Clogged fuel pipe
- Clean
Clogged filter
- Clean
Loose fuel pipe joints
- Tighten additionally or repair
Defective fuel injection pump
Worn plunger
- Replace
Damaged delivery valve
- Replace
Abnormal fuel injection system
Incorrect fuel injection timing
Injection timing too late
- Adjust
Injection timing too early
- Adjust
Defective fuel injection pump
Worn or seized plunger
- Replace
Defective delivery valve
- Replace
Defective delivery valve gasket
- Replace
Defective fuel injector
Seized needle valve
- Make injection test and replace
Worn, damaged or clogged valve seat
- Clean or replace
Defective fuel injector spring
- Make injection test and replace
Clogged nozzle holes
- Clean or replace
Exhaust gas blackish or contains soot pale blue
Abnormal operation of engine itself
Worn liner and piston rings
- Repair or replace
Seized piston rings
- Repair or replace
Defective intake and exhaust valve seats
- Repair by lapping
Tappet clearance too small
- Adjust
Broken intake and exhaust valve springs
- Replace
Gas leakage from loose cylinder head
- Tighten additionally or replace gasket
Leakage from the intake and exhaust manifold systems
- Tighten additionally or replace gasket
Increased resistance of moving parts
- Check and repair
Abnormal turbocharger
Clogged filter (if provided)
- Clean
Blower impeller or turbine blades unclean
- Clean and wash by water injection
Damaged bearing
- Replace
Improper fuel
Improper fuel quality
- Change
Air or water present in fuel oil
- Vent air or replace

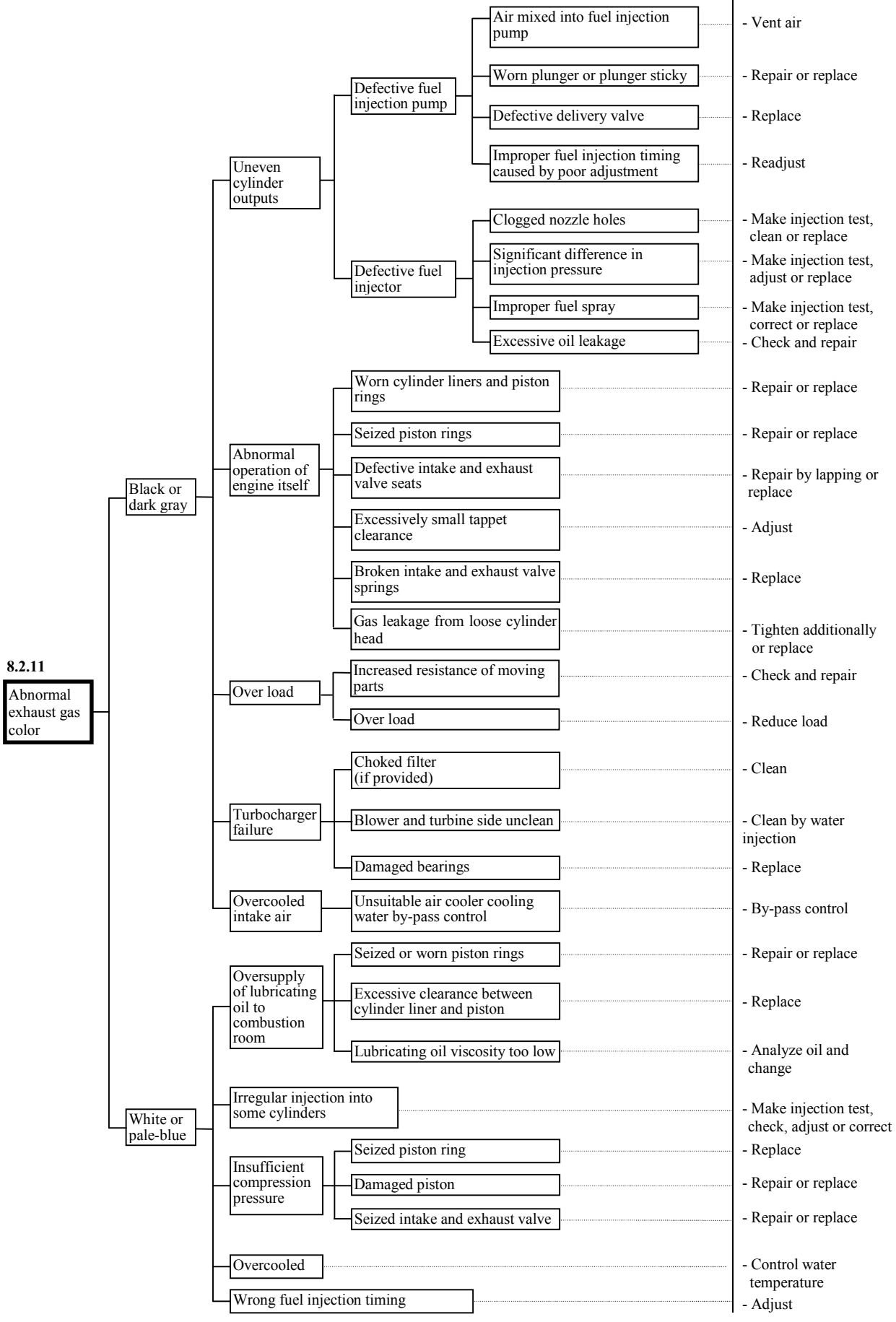

Trouble
Probable Cause
Remedy
8.2.4
Abnormal exhaust gas temperature
Exhaust gas temperature too high
Temperature of all cylinders too high
Over load
Abnormal propeller (rapidly increased exhaust gas temperature) (in case of marine engines)
- Repair or replace
Increased hull resistance (in case of marine engines)
- Clean
Increased engine room temperature
- Ventilate
Turbocharger performance drop
Decrease rpm and charger air pressure
Blower unclean
- Clean by water injection
Turbine blades unclean
- Clean by water injection
Intake filter clogged
- Wash
Air cooler performance drop
Increased intake air temperature
Air cooler unclean
- Clean
Increased temperature of secondary cooling water
- Control water quantity
Reduced intake passage area
Accumulation of carbon in cylinder head intake port
- Clean
Increase exhaust gas back pressure
- Check exhaust manifold system and clean it
Temperature of specific cylinders too high
Defective thermometer
- Replace
Exhaust valve burning
- Repair or replace
Rack scale out of order (advance)
- Readjust
Incorrect fuel injection timing
- Readjust
Abnormal nozzle (enlarged nozzle holes)
- Make injection test and replace
Exhaust gas temperature too low
Temperature of all cylinders too low
Under load
- Normal
Intake air temperature drop
Secondary cooling water temperature drop
- Normal
Temperature of specific cylinders too low
Defective thermometer
- Replace
Abnormal fuel injection pump
Rack scale out of order (delay)
- Readjust
Stuck plunger
- Replace
Broken plunger spring
- Replace
Abnormal fuel injector
Clogged nozzle holes
- Make injection test, clean or replace
Stuck nozzle needle valve
- Make injection test, repair or replace
Leakage from fuel injection pipe
Cracked piping
- Replace
Defective joints
- Repair or replace
Water leakage into cylinders
Water leakage from cylinder head
- Check, repair or replace
Water leakage from exhaust valve cage
- Check, repair or replace

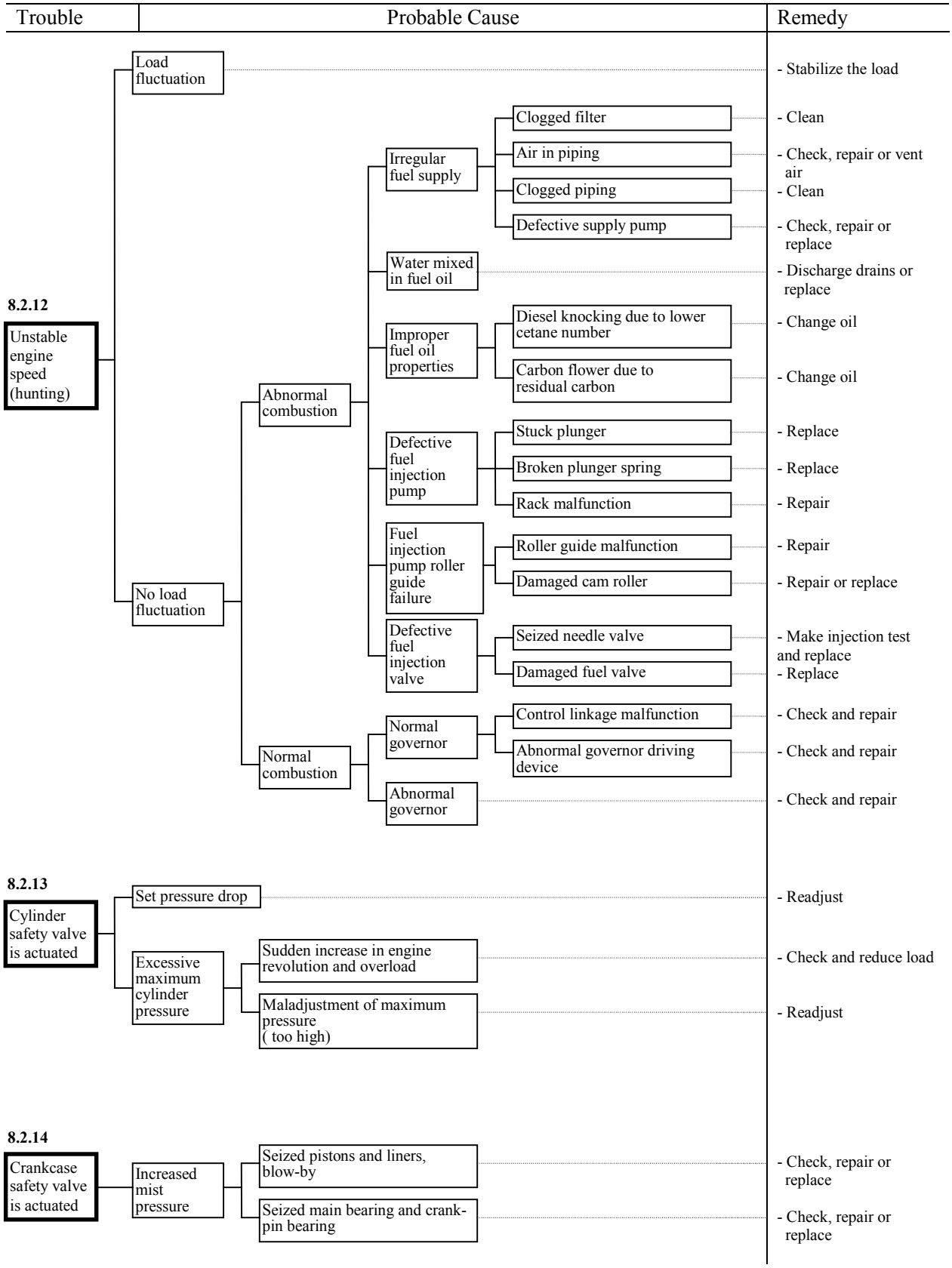

Trouble
Probable Cause
Remedy
8.2.5
Abnormal maximum cylinder pressure
Maximum pressure too high
Increased pressure in all cylinders
Indicator out of order
- Repair or replace
Over load
- Reduce load
Increased charge air pressure
Increased rpm of turbocharger
Clogged turbine nozzle (due to deformation or dirt)
- Overhaul, clean or replace
Increased pressure in specific cylinders
Wrong fuel injection timing
- Readjust
Abnormal fuel injection pump
Stuck rack(at high position)
- Repair or replace
Abnormal fuel injection valve
Enlarged nozzle holes
- Make injection test and replace
Missing nozzle tip
- Replace
Maximum pressure too low
Decreased pressure in all cylinders
Indicator out of order
- Repair or replace
Under load
- Normal
Charge air pressure drop
Turbocharger performance drop (decreased rpm)
Blower side unclean
- Clean by water injection
Turbine side unclean
- Clean by water injection
Increased air cooler resistance
- Clean
Decreased pressure in specific cylinders
Compression pressure drop
Intake and exhaust valves burning
- Repair or replace
Poor gas tightness of piston rings
- Check and replace
Normal compression pressure
Wrong fuel injection timing (delay)
- Readjust
Abnormal fuel injection pump
Stuck rack (at low position)
- Repair or replace
Abnormal fuel injection valve
Stuck needle valve
- Make injection test , repair or replace
Clogged nozzle
- Make injection test , repair or replace
Leakage from fuel injection pipe
Cracked piping
- Replace
Defective joint
- Repair or replace
8.2.6
Abnormal charge air pressure
Pressure too low
Under load
- Normal
Turbocharger performance drop
Blower side unclean
- Clean by water injection
Turbine side unclean
- Clean by water injection
Air leakage from intake manifold system
- Overhaul and clean
Pressure too high
Over load
- Reduce load
Abnormal Turbocharger
Clogged turbine nozzle (due to deformation or dirt)
- Overhaul, clean or replace

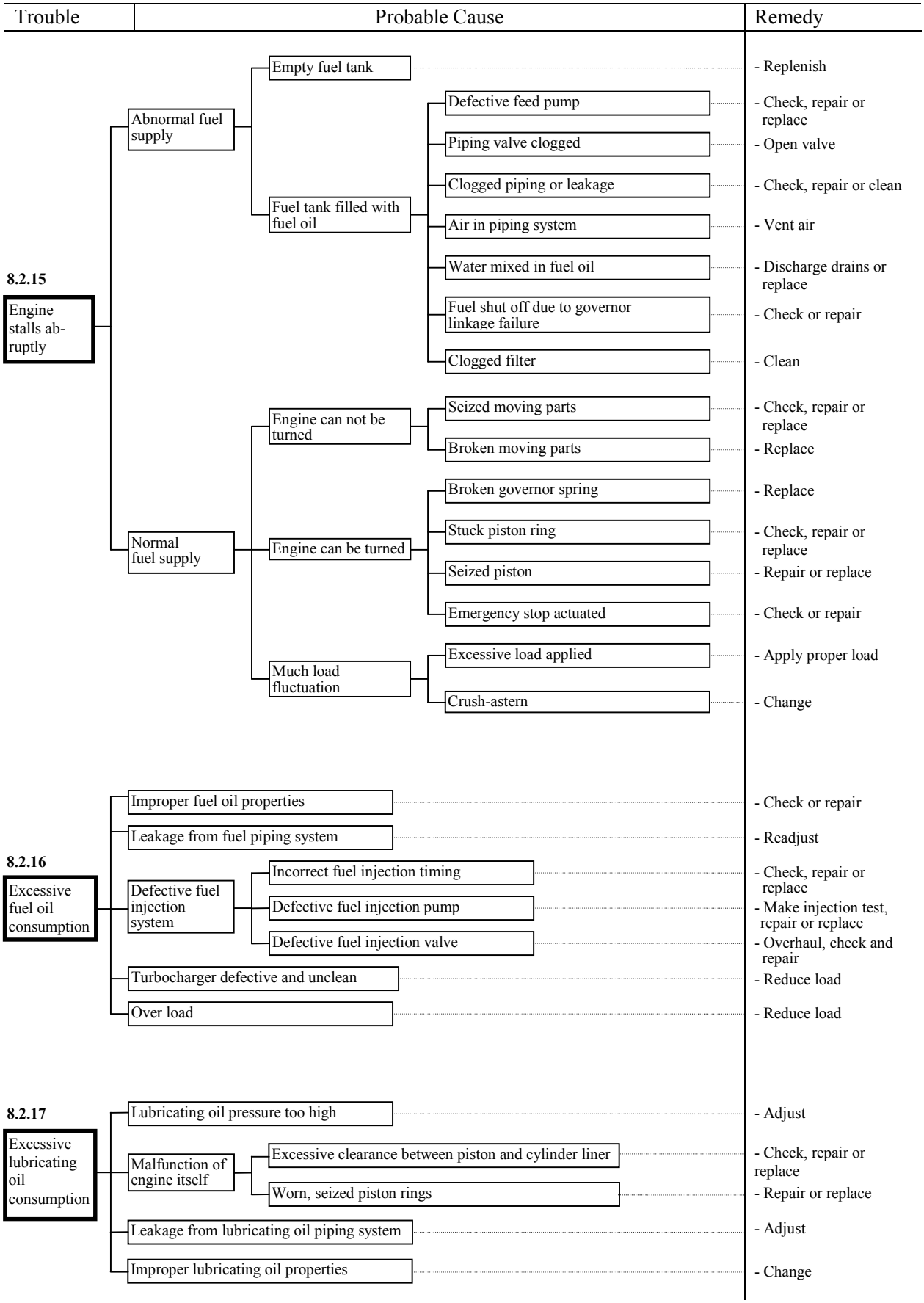

Trouble
Probable Cause
Remedy
8.2.7
Surging of turbo-charger
Decreased air inflow rate
Increased air inflow temperature
Air cooler unclean
Cooling water side
- Clean
Air side
- Clean
Increased temperature of air cooler cooling water
Cooling water pump failure
- Check and repair
Cooling water shortage
- Increase water quantity
Turbo-charger unclean
Intake filter unclean
- Wash
Blower side unclean
- Wash by water injection
Turbine side unclean
- Overhaul and clean
Increased rpm of turbocharger
Reduced nozzle area (nozzle unclean)
- Overhaul and clean
Sudden load change
- Avoid rapid-load change
Not all cylinders operating
- Reduce load
Over load
Over load
- Reduce load
Seized moving parts
- Check, repair or replace
8.2.8
Over-heated engine
Overheated cylinders
Increased cooling water temperature
Cooling water stoppage
Cooling water pump failure
- Check, repair or replace
Cooling water shortage
- Control water quantity
Temperature control valve failure
- Check and readjust
Lowering fresh water cooler performance
- Clean
Seized pistons and liners
- Check, repair or replace
Overheated turbocharger
Cooling water stoppage or shortage
- Check, repair and control
Damaged bearings
- Replace
Overheated fuel injection pump
Stuck plunger
- Replace
Clogged fuel injection valve nozzle
- Make injection test, clean or replace
Overheated intake manifold
Intake valve burning or stuck
- Repair or replace
Overheated cam case door
Cam and cam roller seized
- Repair or replace
Camshaft and bearing seized
- Repair or replace
Overheated crank case door or outer wall
Main bearing and crankpin bearing seized
- Check, repair or replace
Increased temperature of lubricating oil
Cooler performance drop(due to dirt)
- Clean
Overheated gear case
Gear shaft and bush seized
- Repair or replace


Trouble
Probable Cause
Remedy
8.2.9
Engine produces abnormal noise and vibration
Knocking
Fuel injection timing too early
- Readjust
Fuel oil cetane number too low
- Change fuel oil
Irregular injection quantity
- Readjust
Defective fuel injector
Improper fuel spray condition
- Make injection test and replace
Broken fuel injector spring
- Replace
Overcooled engine
- Control water temperature
Abnormal noise generated within gear case
Abnormal gears
Foreign matter caught
- Replace
Damaged gear
- Replace
Excessive backlash
- Check and repair
Abnormal noise generated around cylinder head
Loose bolts and nuts
- Check and tighten additionally
Stuck intake and exhaust valves
- Check, repair or replace
Excessive intake and exhaust valve tappet clearance
- Readjust
Abnormal noise within intake manifold
Stuck intake valve or blow-out of intake valve
- Check, repair or replace
Abnormal noise generated within came case
Damaged cam and cam roller
- Repair or replace
Damaged roller guide
- Repair or replace
Abnormal noise and vibration of turbocharger
Damaged bearings
- Replace
Damaged rotor
Foreign matter caught
- Replace
8.2.10
Abnormal crankcase mist
Increased mist quantity
Piston seized with liner
Cooling water shortage
- Control water quantity
Over load
- Reduce load
Under cooled pistons
Clogged cooling oil passage
- Check and clean
Blow-by
Excessively worn liners and rings
Improper lubricating oil properties
- Analyze oil and replace
Overcooled cylinder
- Check and control water quantity
Main bearing and crankpin bearing seized
Lubricating oil pressure drop
- Check and adjust
Improper lubricating oil properties
Water mixed in oil
- Analyze oil and replace
Color change (pale-blue)
Lubricating oil risen too much
Abnormal oil scraping ring
Excessive wear and breakage
- Check and replace
Excessively worn liner
- Measure wear and replace the liner
Wrong lubricating oil
- Replace brands

Trouble	Probable Cause	Remedy

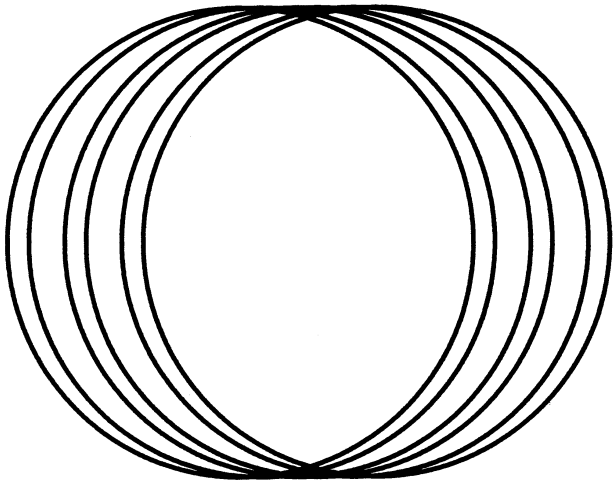

8.2.11
Abnormal exhaust gas color
Black or dark gray
White or pale-blue
Uneven cylinder outputs
Defective fuel injection pump
Air mixed into fuel injection pump
- Vent air
Worn plunger or plunger sticky
- Repair or replace
Defective delivery valve
- Replace
Improper fuel injection timing caused by poor adjustment
- Readjust
Defective fuel injector
Clogged nozzle holes
- Make injection test, clean or replace
Significant difference in injection pressure
- Make injection test, adjust or replace
Improper fuel spray
- Make injection test, correct or replace
Excessive oil leakage
- Check and repair
Abnormal operation of engine itself
Worn cylinder liners and piston rings
- Repair or replace
Seized piston rings
- Repair or replace
Defective intake and exhaust valve seats
- Repair by lapping or replace
Excessively small tappet clearance
- Adjust
Broken intake and exhaust valve springs
- Replace
Gas leakage from loose cylinder head
- Tighten additionally or replace
Over load
Increased resistance of moving parts
- Check and repair
Over load
- Reduce load
Turbocharger failure
Choked filter (if provided)
- Clean
Blower and turbine side unclean
- Clean by water injection
Damaged bearings
- Replace
Overcooled intake air
Unsuitable air cooler cooling water by-pass control
- By-pass control
Oversupply of lubricating oil to combustion room
Seized or worn piston rings
- Repair or replace
Excessive clearance between cylinder liner and piston
- Replace
Lubricating oil viscosity too low
- Analyze oil and change
Irregular injection into some cylinders
- Make injection test, check, adjust or correct
Insufficient compression pressure
Seized piston ring
- Replace
Damaged piston
- Repair or replace
Seized intake and exhaust valve
- Repair or replace
Overcooled
- Control water temperature
Wrong fuel injection timing
- Adjust


Trouble
Probable Cause
Remedy
8.2.12
Unstable engine speed (hunting)
Load fluctuation
- Stabilize the load
No load fluctuation
Abnormal combustion
Irregular fuel supply
Clogged filter
- Clean
Air in piping
- Check, repair or vent air
Clogged piping
- Clean
Defective supply pump
- Check, repair or replace
Water mixed in fuel oil
- Discharge drains or replace
Improper fuel oil properties
Diesel knocking due to lower cetane number
- Change oil
Carbon flower due to residual carbon
- Change oil
Defective fuel injection pump
Stuck plunger
- Replace
Broken plunger spring
- Replace
Rack malfunction
- Repair
Fuel injection pump roller guide failure
Roller guide malfunction
- Repair
Damaged cam roller
- Repair or replace
Defective fuel injection valve
Seized needle valve
- Make injection test and replace
Damaged fuel valve
- Replace
Normal combustion
Normal governor
Control linkage malfunction
- Check and repair
Abnormal governor driving device
- Check and repair
Abnormal governor
- Check and repair
8.2.13
Cylinder safety valve is actuated
Set pressure drop
- Readjust
Excessive maximum cylinder pressure
Sudden increase in engine revolution and overload
- Check and reduce load
Maladjustment of maximum pressure (too high)
- Readjust
8.2.14
Crankcase safety valve is actuated
Increased mist pressure
Seized pistons and liners, blow-by
- Check, repair or replace
Seized main bearing and crank-pin bearing
- Check, repair or replace


Trouble
Probable Cause
Remedy
8.2.15
Engine stalls abruptly
Abnormal fuel supply
Empty fuel tank
- Replenish
Fuel tank filled with fuel oil
Defective feed pump
- Check, repair or replace
Piping valve clogged
- Open valve
Clogged piping or leakage
- Check, repair or clean
Air in piping system
- Vent air
Water mixed in fuel oil
- Discharge drains or replace
Fuel shut off due to governor linkage failure
- Check or repair
Clogged filter
- Clean
Normal fuel supply
Engine can not be turned
Seized moving parts
- Check, repair or replace
Broken moving parts
- Replace
Engine can be turned
Broken governor spring
- Replace
Stuck piston ring
- Check, repair or replace
Seized piston
- Repair or replace
Emergency stop actuated
- Check or repair
Much load fluctuation
Excessive load applied
- Apply proper load
Crush-astern
- Change
8.2.16
Excessive fuel oil consumption
Improper fuel oil properties
- Check or repair
Leakage from fuel piping system
- Readjust
Defective fuel injection system
Incorrect fuel injection timing
- Check, repair or replace
Defective fuel injection pump
- Make injection test, repair or replace
Defective fuel injection valve
- Overhaul, check and repair
Turbocharger defective and unclean
- Reduce load
Over load
- Reduce load
8.2.17
Excessive lubricating oil consumption
Lubricating oil pressure too high
- Adjust
Malfunction of engine itself
Excessive clearance between piston and cylinder liner
- Check, repair or replace
Worn, seized piston rings
- Repair or replace
Leakage from lubricating oil piping system
- Adjust
Improper lubricating oil properties
- Change

Trouble	Probable Cause	Remedy
8.2.18 Lubricating oil pressure gauge malfunction	Pressure gauge pointer does not rise after engine start: Lubricating oil shortage	- Replenish
	Pressure gauge pointer does not rise after engine start: Lubricating oil viscosity too low	- Analyze oil and change
	Pressure gauge pointer does not rise after engine start: Defective lubricating oil pressure sensor	- Replace
	Pressure gauge pointer does not rise after engine start: Clogged pressure gauge sensor piping	- Clean
	Pressure gauge pointer does not rise after engine start: Excessive bearing clearance	- Check, repair or replace
	Pressure gauge pointer does not rise after engine start: Lubricating oil pump malfunction: Air inhalation into suction piping	- Check, repair or vent air
	Pressure gauge pointer does not rise after engine start: Lubricating oil pump malfunction: Clogged suction piping or filter	- Clean
	Pressure gauge pointer does not rise after engine start: Lubricating oil pump malfunction: Worn gear case	- Check and replace
	Pressure gauge pointer does not rise after engine start: Lubricating oil pump malfunction: Pressure regulating valve failure	- Check, repair or replace
	Pressure gauge pointer does not rise after engine start: Clogged filter	- Clean
	Pressure gauge pointer drops suddenly during operation: Excessive oil leakage caused by damaged piping or cooler	- Check, repair or replace
	Pressure gauge pointer drops suddenly during operation: Blind plug for oil hole fallen off	- Check and attach plug
	Pressure gauge pointer drops suddenly during operation: Cracked lubricating oil piping or leakage from joints	- Repair
	Pressure gauge pointer oscillates during operation: Air inhalation through inlet due to lubricating oil shortage	- Replenish
	Clogged lubricating oil piping	- Check and clean
	Poorly adjusted pressure regulating valve	- Adjust

8.2.19 Cases where engine requires emergency stop	Engine revolution has risen spontaneously or cannot be controlled
	Fuel scale pointer abnormally advanced and engine revolution dropped
	Bearings or other moving parts overheated
	Engine produces abnormal vibration
	Engine produces abnormal noise
	Mist in crankcase abnormal in quantity or color
	Lubricating oil pressure sudden drop
	Cooling water temperature sudden rise
	Turbo-blower produces abnormal noise, vibration or heat



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9. APPENDIX

9.1 Lubricating oil system flushing procedure

When an engine is newly installed, or when the engine is overhauled, the lubricating oil system must be flushed to remove sludge and other foreign matter. This Manual describes a standard flushing procedure, and it must be understood that, particularly when an engine is newly installed, a special method may have to be used because the amount and kind of foreign matter in the piping may vary. Choose an appropriate method as instructed by your installation advisor.

9.1.1 Cases requiring flushing

(a) Newly installed engine

The first stage to the third flushing mentioned later is necessary for removing scale, dust, etc. Generated by piping and welding.

(b) Overhauled engine

A flushing similar to that applied to a newly installed engine is necessary to remove substances resulting from lubricating oil deterioration and combustion.

(c) Change of lubricating oil

The first to the third flushing are necessary for removing substances resulting from lubricating oil deterioration and preventing fresh oil contamination. Particularly when using heavy fuel oil, flushing is important for washing away the burnt residues that have been deposited on various parts.

(d) Other

If foreign matter is suspected to have entered the lubricating oil system accidentally, flush the system in a similar way.

9.1.2 Parts requiring flushing

(1) Lubricating oil circulation system

- Sump tank, lubricating oil pump, cooler, filters, temperature control valve, bypass valves, and pipes connecting them
- Crankcase and Oil pan
- Lubricating oil return pipe (Engine → Sump tank)
- Engine inside oil paths - The third flushing only.

9.1.3 Preparations for Flushing

(1) Parts not flushed

In the case of the first stage and the second stage flushing, engine inside oil paths are not flushed, therefore the oil engine inlet pipe have to be disconnected and to be led into the crankcase by connecting a temporary pipe or a hose.

(2) Have a temporary pump and filter (First stage ; 150-mesh. Second stage ; 250-mesh.), if equipped pumps and filters are not available.

(3) Temporary filter mounting

At the outlet of the temporary pipe in the crankcase, put a basket type filter of 250-mesh gauze wire to collect and remove foreign matter.

9.1.4 Flushing Oil

(1) Flushing oil selection

Various brands of flushing oil are available from oil makers. Ask them for advice. Flushing conditions.

(2) Flushing oil amount

Fill the sump tank to more than 60% of its capacity with flushing oil. Record the amount of flushing oil put into the sump tank to check against the amount of oil withdrawn later.

(3) Oil circulating temperature

Standard oil circulating temperature at the engine inlet is 60 to 80°C (First stage) and 50 to 70°C (Second stage). If the oil temperature is lower than that, use a heater to heat the oil.

(4) Oil pressure

Fit pipe outlet in the crankcase with a suitable throttle so that the flushing oil will circulate full in the piping. This is necessary because the oil is not supplied to the inside of the engine. Be careful of differential filter pressure because large amounts of foreign matter may flow into the filter when oil circulation through the filter is started.

9.1.5 Flushing

(1) A flushing schedule is shown below.

Flushing	Oil	Oil temperature (°C)	Oil pressure (MPa)	Hours	Piping
First stage flushing	Flushing oil	60 ~ 80	0.1 ~ 0.2	72	Engine inlet pipe is Disconnected and oil Returns directly to the crankcase. -Temporary piping
Second stage flushing	Normal Lubricating oil	50 ~ 70	0.1 ~ 0.2	2	Same as above
Third stage flushing	Normal Lubricating oil	50 ~ 70	0.4 ~ 0.6	3	Normal piping

※The first stage and the second stage flushing, engine inside oil paths are not flushed.

(2) Record the following information to use as data for judging flushing condition and in order to thoroughly control the flushing process as a whole.

Data	Time	Cumulative oil circulation time	Lubricating Oil pump Pressure (MPa)	Lubricating oil filter pressure		Oil temperature (°C)	Foreign matter						Remarks
				Outlet	Inlet		Sand	Fiber	Iron rust	Spatter	Paint	Sludge	

(3) The filters tend to be clogged with foreign matter immediately after flushing begins.
(4) Hammering is necessary to completely remove scale after welding.
(5) Collect foreign matter with the temporary filter and the equipped filters.
(6) As a rule, foreign matter should be collected and various parts checked every 4 hours.
(7) Ideally, flushing should be continued until foreign matter has been completely removed. If no foreign matter is seen caught by the filters, however, the flushing may be regarded as nearly finished. End the first stage flushing when the amount of foreign matter caught by the temporary filter on the main bearing branch pipe is less than 0.05g/24 hours.
(8) After finishing the first flushing, discharge all the flushing oil from the system. Because a considerable amount of flushing oil may remain in the cooler, filters and the bottom parts of the piping, discharge all the oil and measure the quantity of oil withdrawn. If a very large amount of flushing oil remains, it will dilute the system oil and consequently deteriorate it. The allowable amount of remaining flushing oil is less than 5% of the amount of system oil used.
(9) Clean the inside of the sump tank and the bottom of the oil pan (before filling the system with flushing oil, and after the flushing oil is discharged following the completion of the first flushing). Use oil-resistant sponge, not waste cloth, for cleaning.
(10) After finishing the above, fill the system with recommended lubricating oil, and circulate it under the required conditions for the second flushing.
(11) Be careful of differential filter pressure during the second flushing. Discharge drains, and make sure that no foreign matter has collected in the blow filter.
(12) After finishing the second flushing, remove the temporary filter, and reconnect the engine inlet pipe normally, observing the checking instructions above to prevent any difficulties.
(13) During the third flushing, check the filter differential pressure and discharge drains to see that the oil is free of foreign matter. Also, thoroughly vent air from the cooler and filters. Turn the engine (making use of the turning device) for about 30 minutes at the same time. This third flushing has the dual purpose of internal flushing and priming.